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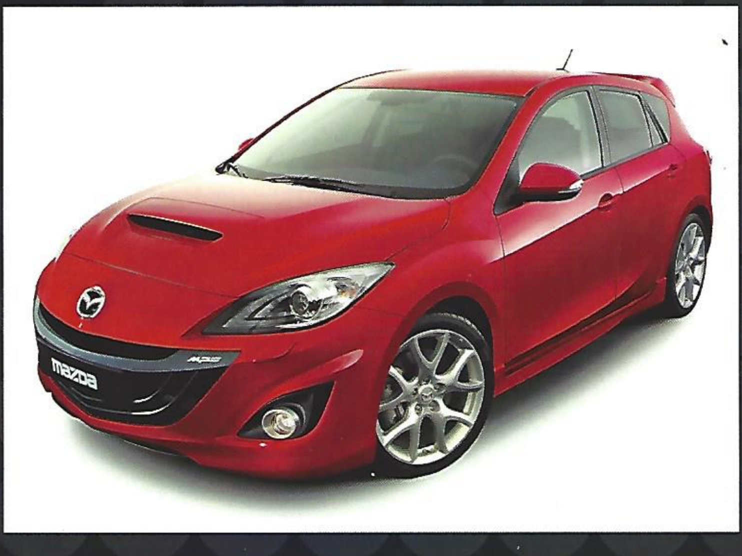
Technical Training Manual

Direct Petrol Injection



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Direct Petrol Injection (DPI)
Fundamentals, Operation, Servicing and Diagnosis

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INTRODUCTION

Direct Petrol Injection (DPI) is one of many generic terms for fuel injection systems that are replacing the common port fuel injection systems. DPI has been in use for many years; initially in a mechanical form. It has been used in aircraft during WWII and many vehicles since then. It is only with modern technology; including fuels, that DPI is able to reach its full potential. DPI is the next phase in further improvements to the Internal Combustion Engine.

From the outside, DPI can seem simple. Fuel is now injected directly into the cylinder instead of into the intake port. However, DPI allows the engineers to have greater control over the events inside the combustion chamber.
Prior to DPI, once the intake valve closed; apart from spark timing, they had little; to no further control over what happened inside the combustion chamber.

Benefits of DPI

Improved engine efficiency through:

- Higher compression ratio - can be used with standard fuels
- Volumetric efficiency - only air travels through the intake port - no port/manifold wetting
- Reduced pumping loss - when cruising, energy not wasted creating manifold vacuum
- More power and torque - from smaller engines
- Reduced emissions.

Over Port Fuel Injection, DPI also creates a lot more development work to get it to work properly as there are now additional variables to be developed and programmed:

- Injection timing
- Number of injections per cycle
- Spacing between multiple injections
- Shifting between injection modes - homogenous, stratified or mixed modes
- NO_X emission output can be trimmed with variations in injection timing.

Quantum leap like Common Rail Diesel

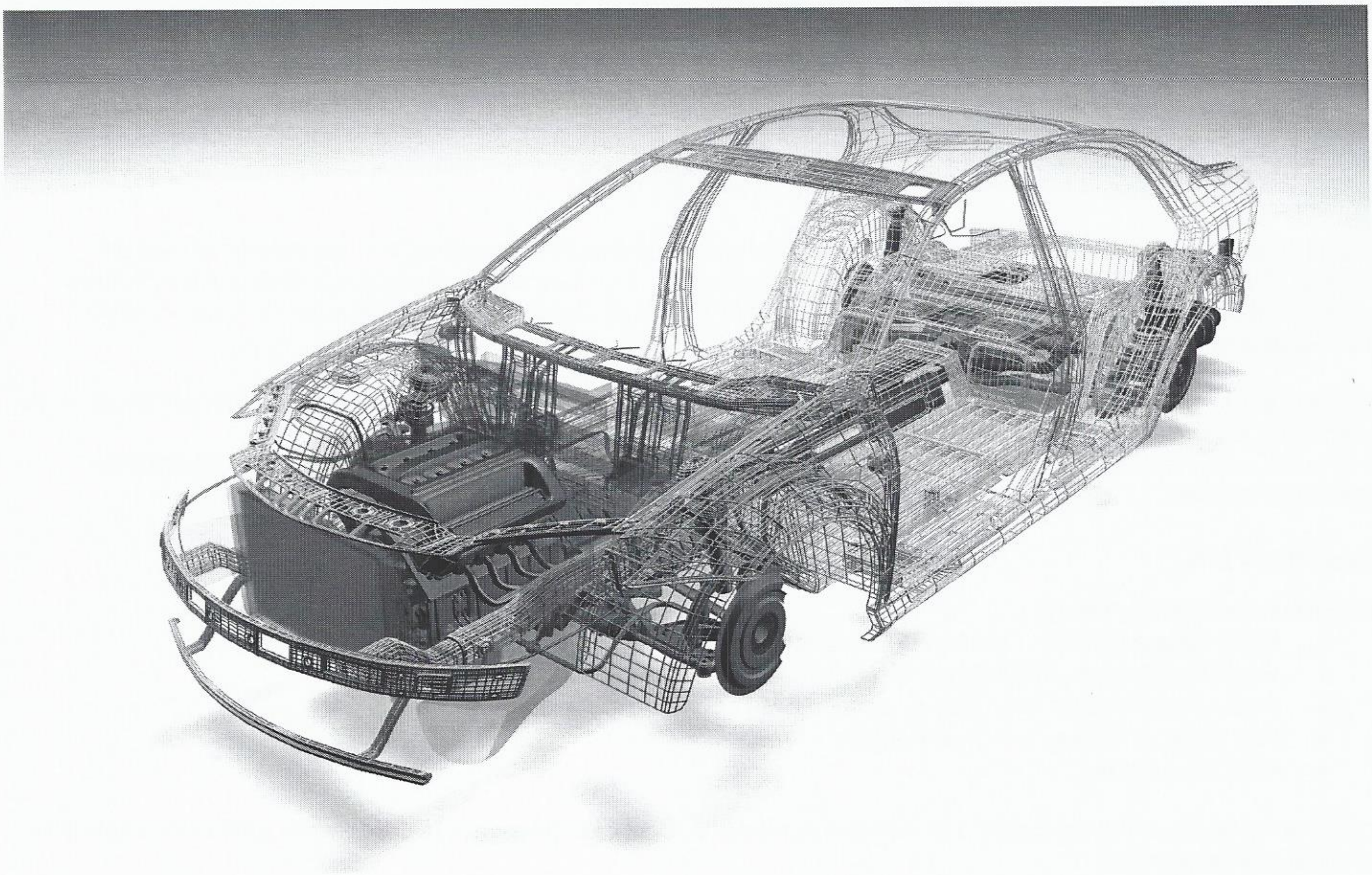
To those familiar with the changes that the Common Rail Diesel engine has received over old style diesel 'clunker' engines, in recent years there is a similar leap forward in the move from port petrol placement (try saying that quickly 3 times) injection to direct petrol injection.

- At times – no intake throttling – greater volumetric efficiency and lower pumping losses
- At times – multiple injections per cycle – faster operating injectors
- Higher injection pressures - up to 15 MPa
- Variable injection points – now electronically controlled
- Higher compression - greater thermal efficiency.

Manufacturer Identification

All manufacturers have identification codes/abbreviations for their DPI Systems, below are some examples:

CGI	Charged Gasoline Injection (BMW & Mercedes Benz)
DIG-S	Direct Injection Gasoline – Supercharger (Nissan)
DISI	Direct Injection Spark Ignition (Mazda)
FSI	Fuel Stratified Injection (VW, Audi, Seat &Skoda)
GDI	Gasoline Direct Injection (registered trademark of Mitsubishi and also used by Hyundai)
GTDI	Gasoline Turbocharged Direct Injection (EcoBoost – Ford)
IDE	Injection Direct Essence (Renault)
JTS	Jet Thrust Stoichiometric (Alfa Romeo)
SCi	Smart Charge injection (Ford Euro)
SIDI	Spark Ignition Direct Injection (GM)



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Look for the symbols throughout the manual

Note: Indicates a point of interest

Caution: Indicates the risk of minor injury, special procedure or possible damage to a component

Warning: Indicates the risk of serious or life threatening injury

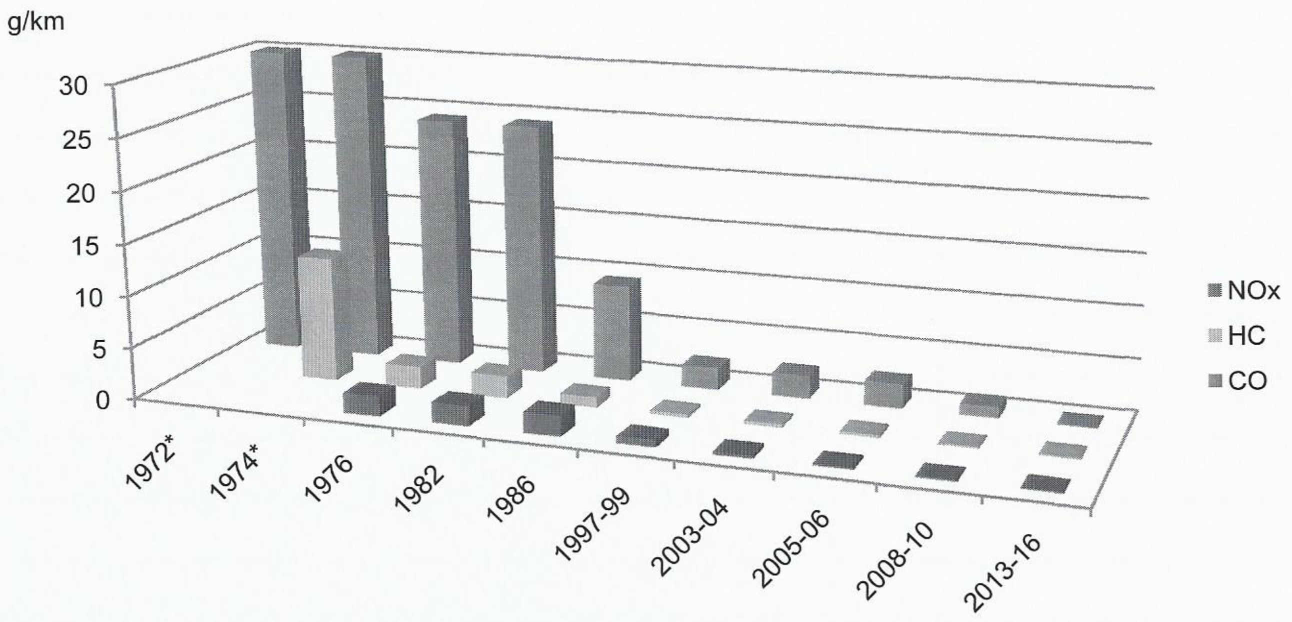
Operating Fundamentals

WHY DPI

The need for a more efficient and cleaner way of powering vehicles is required by manufacturers to meet the governments environmental management regulations, while at the same time the performance of the vehicle needs to be improved to feed the consumers requirements. Although there are alternative vehicle options available such as Electric or Hybrid vehicles, at the present time they are not a suitable replacement for all consumers and the petrol powered internal combustion engine is still the most economical to produce and maintain.

Every few years the government reduces the acceptable levels of emission for all vehicles (we will only focus on the petrol vehicles at this time). This helps to offset the growing number of vehicles on the road each year (just one of the many factors involved).
According to the Australian Bureau of Statistics the number of registered vehicles in Australia increased by 15.4% (12.6% for passenger cars) in the 5 years from 2005 to 2010. This equates to an annual increase of 2.9%. In *Figure 1*, you can see a graphical representation of these reductions over a forty year period and *Table 1* provides the full emission table through to 2016.

Figure 1: Emission levels by year



* Indicative ONLY – measured on a different method

Table 1: Summary of Emission Requirements for New Petrol Passenger Cars In Australia 1972-2010

Standard	Date Introduced	Exhaust Emission Limits (petrol vehicles)			Source Standard / Test Method
		HC	CO	NO_x	
ADR26	01/01/1972	N/A	4.5% by volume	N/A	Idle CO test
ADR27	01/01/1974	8.0 – 12.8 g/test	100 – 200 g/test & 4.5% by vol.	N/A	ECE 'Big Bag'
ADR27A	01/07/1976	2.1 g/km	24.2 g/km	1.9 g/km	US '72 FTP
ADR27B	01/01/1982	2.1 g/km	24.2 g/km	1.9 g/km	US '72 FTP
ADR27C+	01/01/1983	2.1 g/km	24.2 g/km	1.9 g/km	US '72 FTP
ADR37/00	01/02/1986	0.93 g/km	9.3 g/km	0.63 g/km	US '75 FTP
ADR37/01	01/01/1997 – 01/01/1999	0.26 g/km	2.1 g/km	0.63 g/km	US '75 FTP
ADR79/00	01/01/2003 – 01/01/2004	0.25 g/km*	2.2 g/km	0.25 g/km*	UN ECE R83/04 (Euro 2)
ADR79/01	01/01/2005 – 01/01/2006	0.2 g/km	2.3 g/km	0.15 g/km	UN ECE R83/05 (Euro 3)
ADR79/02	01/07/2008 – 01/07/2010	0.1 g/km	1.0 g/km	0.08 g/km	UN ECE R83/05 (Euro 4)
ADR79/03	01/04/2013	0.1 g/km	1.0 g/km	0.06 g/km	UN ECE R83/06 (Euro 5)~
ADR79/04	01/04/2015	0.1 g/km	1.0 g/km	0.06 g/km	UN ECE R83/06 (Euro 5)~
ADR79/05	2017 - 2018	0.1 g/km	1.0 g/km	0.06 g/km	UN ECE R83/?? (Euro 6)

+ ADR27C introduced a number of administrative changes, based on procedures of ADR37/00

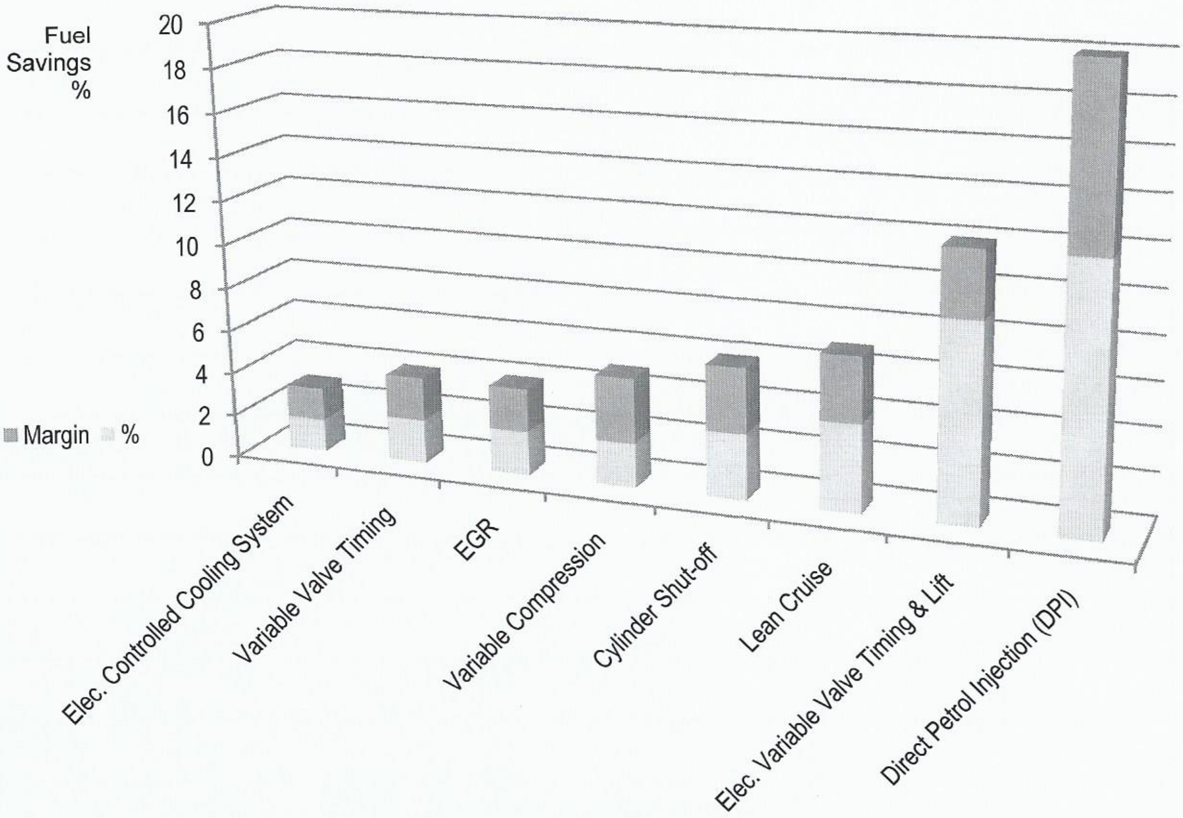
* ADR 79/00 has a combined HC+NO_x of 0.5 g/km, so the HC:NO_x split is indicative only

~ ADR79/03 will introduce the core components of Euro 5 with full compliance being met in ADR79/04

WHY DPI continued...

This leads manufactures to develop ways of making the Petrol Engine more efficient.
Figure 2 shows the fuel saving benefits of different types of technology when applied to a Petrol Engine. Many of these can be combined together for increased benefits (Note: The Margin shown in dark grey is the difference between minimal and optimal improvement).

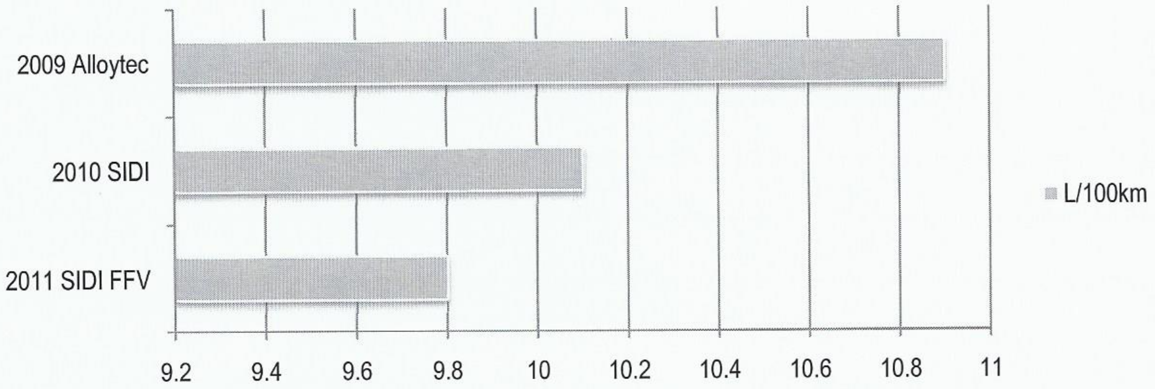
Figure 2: Technological measures to improve fuel efficiency



As *Figure 2* clearly demonstrates, the greatest potential gain in fuel efficiency can be achieved with the implementation of DPI. Many manufacturers using DPI technology are also using Electronic Variable Valve Timing and Lift which means the two most beneficial measures are being coupled together for maximum benefit.

A good example of the improvement achieved with DPI can be measured by comparing the 2007MY 3.6L VE Commodore which utilised Port Fuel Injection with its successor the 2010MY 3.6L SIDI VE Commodore which utilises DPI, see *Figure 3*. It is also note worthy to point out that the following values were achieved without using the full potential of DPI (see: sections on Stratified Charge Mode and NO$_X$ Control for full details). Some manufactures claim their DPI powered vehicles are achieving better Fuel Economy values than comparable Common Rail Diesel vehicles.

Figure 3: Holden VE Commodore, Combined Fuel Economy



WHY DPI continued...

An additional benefit is increased performance. Many manufacturers are achieving increased power & torque outputs from equivalent engine capacities. Some examples of these can be seen in *Table 2*.

Table 2: Comparison between like models

Model Year	Make	Model	Engine Capacity	Delivery	Power	Torque
2004	Lexus	GS300	3.0L I6 with VVT	MPFI	166kW @ 6000rpm	298Nm @ 4000rpm
2005				DPI	183kW @ 6200rpm	310Nm @ 3500rpm
2004	Volkswagen	Golf GTi	1.8L with VVT& Turbo	MPFI	110kW @ 5700rpm	210Nm @ 1750rpm
2006		Jetta	2.0L with VVT	DPI	110kW @ 6000rpm	200Nm @ 3500rpm
2005		Golf GTi	2.0L with VVT& Turbo	DPI	147kW @ 5100rpm	280Nm @ 1800-5000rpm
2007	Mazda	3 SP23	2.3L I4 with VVT	MPFI	115kW @ 6500rpm	203Nm @ 4500rpm
		3 MPS	2.3L I4 with VVT & Turbo	DPI	190kW @ 5500rpm	380Nm @ 3000rpm
2009.5	Holden	Commodore	3.6L V6 with VVT	MPFI	195kW @ 6500rpm	340Nm @ 2600rpm
2010				DPI	210kW @ 6400rpm	350Nm @ 2900rpm
2010	Hyundai	Sonata	2.4L with VVT	MPFI	127kW @ 6000rpm	225Nm @ 4000rpm
		I45		DPI	148kW @ 6300rpm	250Nm @ 4250rpm

OPERATING MODES

The DPI engine utilises two main Charge Types that can be used in a number of Operating Modes.

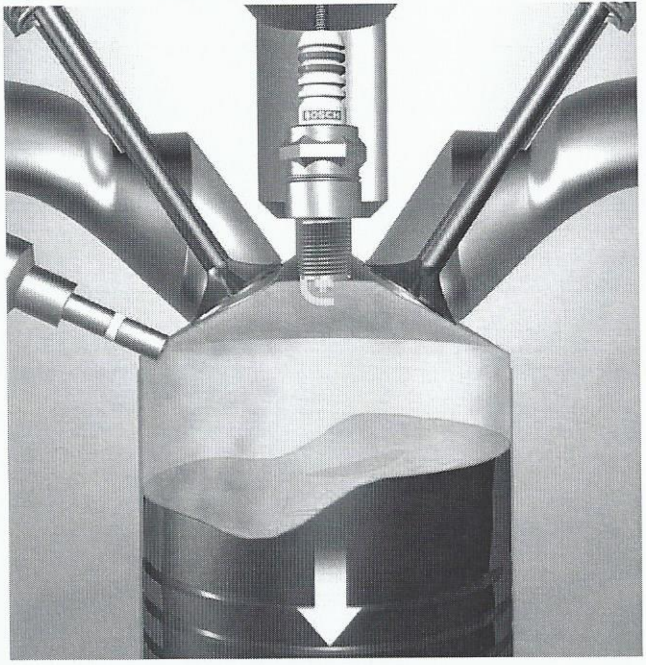
Charge Types:

Homogeneous

The word homogeneous (pronounced ho-mo-ge-ne-ous) in its current context means "Uniform in composition throughout".

This describes the composition of the air and fuel mixture in the combustion chamber. This charge type is the charge type achieved in Port Fuel Injection (PFI) and for DPI engines operating under one of the homogeneous modes.

Figure 4: Homogeneous Charge

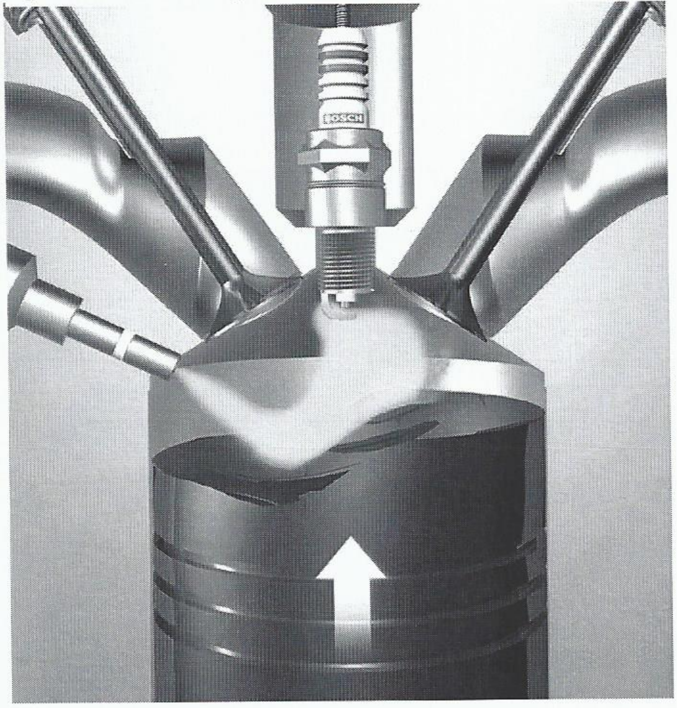


OPERATING MODES continued...

Stratified

The word Stratified in its current context means "To become layered; [to] form Strata".
This describes the formation of the air and fuel mixture around the Sparkplug, while the remainder of the combustion chamber is filled with a mixture of air and exhaust gases.

Figure 5: Stratified Charge



OPERATING MODES continued...

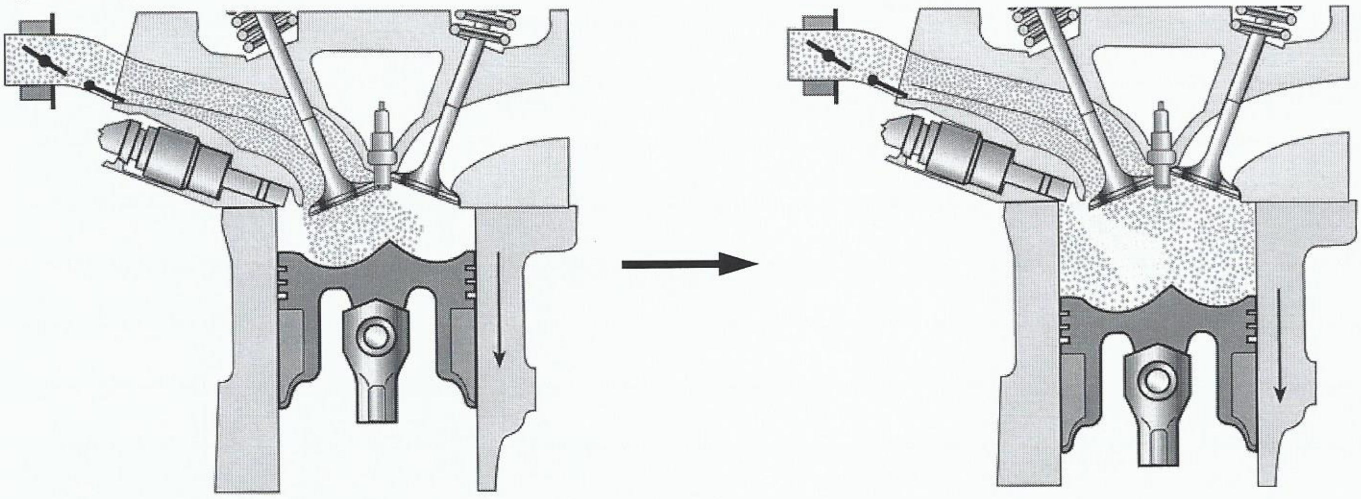
Operating Modes:

Homogeneous Charge Mode

In the Homogeneous Charged Mode fuel is injected in to the cylinder during the Intake Stroke (at approx. 300° before ignition TDC). This allows plenty of time for the air and fuel to mix into a uniform mixture at around stoichiometric value (air/fuel=14.7:1 or Lambda=1).

Figure 6: Intake

Figure 7: Fuel Injection

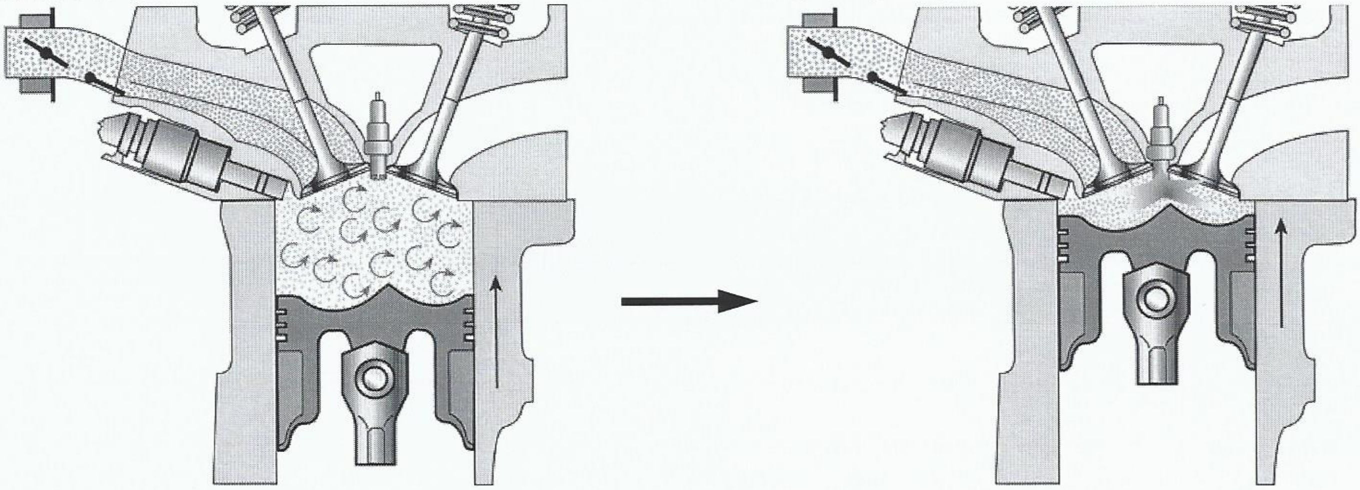


During the intake stroke the Intake Manifold Runner Valve is opened to provide the most efficient air flow into the cylinder. Due to the removal of the fuel in the intake manifold the cylinder draws a full charge of air in (this increases volumetric efficiency over Port Fuel Injection by approximately 6.8%).

With the fuel being injected directly into the combustion chamber the atomisation of the fuel creates a cooling effect, this lowers the temperature in the combustion chamber causing the air/fuel mixture in the cylinder to contact and draw further air through the still open Intake Valve.

Figure 8: Compression

Figure 9: Ignition



During compression the air and fuel continue to mix into a uniform stoichiometric mixture (air/fuel=14.7:1 or Lambda=1). In much the same way as a Port Fuel Injection engine.

Ignition is timed at the same timing and method as a typical Port Fuel Injection engine.

The benefits of Homogeneous Charge DPI over typical Port Fuel Injection are:

- Less NO_X are created than in Stratified Charge
- Increased volumetric efficiency
- More efficient at high engine speeds

OPERATING MODES continued...

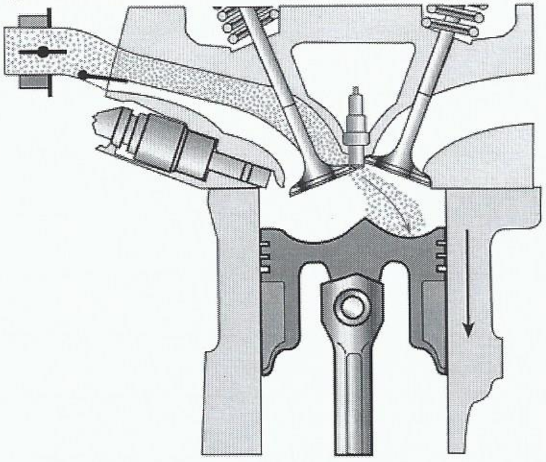
Stratified Charge Mode

In the Stratified Charge Mode fuel is injected into the cylinder during the compression stroke. As the piston continues to rise air forces within the cylinder lift or hold a very rich mass of highly combustible air and fuel (or charge) around the sparkplug. The remainder or the cylinder is filled with a combination of very lean air fuel mixture and exhaust gases.

The total air/fuel ratio in this mode can be up to 60:1 (Lambda 4) and the exhaust gases help to reduce some of the NO_X emissions created in the lean burn.

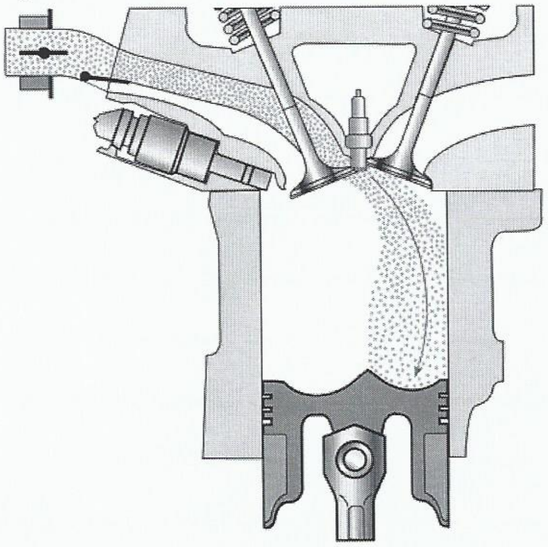
Stratified Charge is best utilised in the low to medium engine torque and speed range (cruise). At higher engine speeds the turbulence in the cylinder prevents the charge from reaching its required destination, the sparkplug.

Figure 10: Intake Stroke



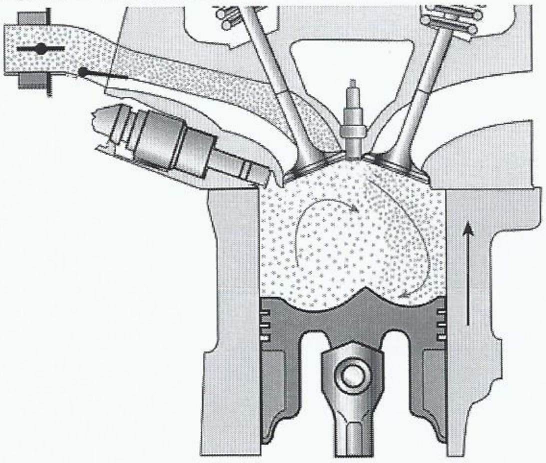
During the intake stroke the Intake Manifold Runner Valve is actuated to direct the air down one side of the cylinder. The Throttle Valve is also at or near to fully open, reducing restriction in the intake system known as 'Throttle Losses'.

Figure 11: BDC



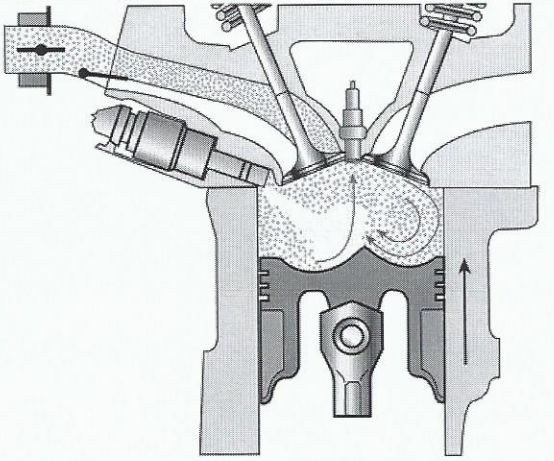
This starts the air swirling in the cylinder which is an important first stage of DPI.

Figure 12: Compression



On the compression stroke the swirling mixture of air and exhaust gases intensifies.

Figure 13: Injection



The fuel is then injected into the centre of the combustion chamber or piston. Due to the difference in velocity the rich air fuel mixture is held in the centre of the combustion chamber and strata is formed.

OPERATING MODES continued...

Figure 14: Pre-combustion

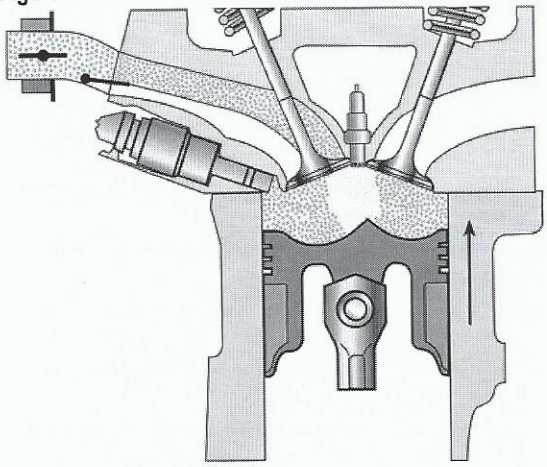
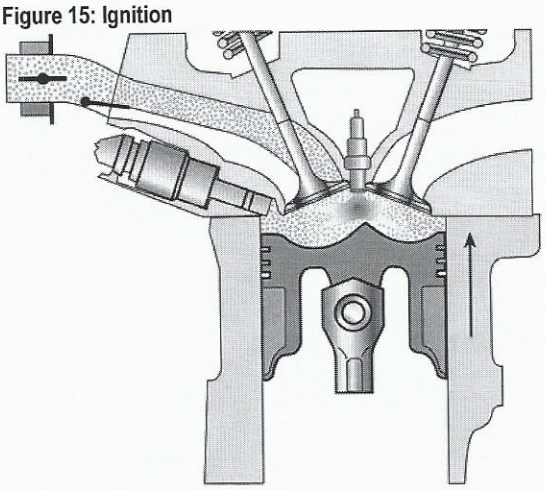


Figure 15: Ignition



Just prior to ignition the small dense charge of highly combustible air and fuel is surrounding the sparkplug.

Once ignited, the fuel burns around the sparkplug while air and exhaust gas mixture swirl around the perimeters of the combustion chamber. Thus insulating combustion from the cylinder walls and providing greater thermal efficiency.

The benefits of Stratified Charge over Homogeneous Charge DPI are:

- Very lean charge creates high fuel efficiency
- Increased thermal efficiency allowing higher compression ratios
- More efficient at low to mid engine speeds

Note: *A side effect of Stratified Charge is the dramatic increase in Oxides of Nitrogen (NOX) in the exhaust gases. To run full Stratified Charge the vehicle must be equipped with a NO_X control system. Current sulphur levels impair the operation of the NO_X control system, for this reason full Stratified Charge Mode is not utilised.*

OPERATING MODES continued...

Mixed & Sub Modes

Homogeneous Lean Charge Mode

Homogeneous Lean Charge Mode is a sub mode of the typical Homogeneous Charge Mode.
As with Homogeneous Mode the fuel is injected into the cylinder on the intake stroke, but the amount of fuel is less than normal.
Simultaneously the Throttle Valve operation changes and is opened to a greater amount, reducing throttle losses and allowing extensive air flow into the cylinder.
In this Homogeneous Lean Charge Mode the air/fuel ratio is up to 22.8:1 (Lambda 1.55).

Note: *For markets not optimised with full Stratified Charge Mode, Homogeneous Lean Charge Mode becomes the main economy cruise operation mode.*

Homogeneous Stratified

Homogeneous Stratified mode is only activated for very few engine cycles during the change over between Stratified and Homogeneous. A lean mixture of fuel is injected on the intake stroke the same as Homogeneous lean but a second injection is also used on the compression stroke. With this mode engine torque can be managed more accurately and NO_X emission levels are reduced.

Homogeneous Split

This mode is used to rapidly heat the catalytic converter to bring it to its operating temperature quicker so then producing fewer emissions. The injector operates on the intake stroke and then again on the power stroke. With this operation ignition timing can be retarded to such a point that heat energy that's left over from the power stroke is used to heat the exhaust instead of producing torque. This mode operates for the first 20 to 40 seconds after start up.

Homogeneous Knock Prevention Mode

During the course of Homogeneous Knock Prevention mode double injection is used when the engine is at full load. By using the fuel in this case, ignition timing does not have to be retarded and a higher torque can be produced by the engine. Instead we rely on good old fashioned Ignition Timing.

Note: *For markets not optimised with full Stratified Charge Mode, retarding of the Ignition Timing is still required for Knock Prevention.*

Stratified charge starting

When the engine is being started it uses stratified injection on the compression stroke only. This way the fuel vaporises without forming any wall films which in turn produces less hydrocarbons (HC's). Not all manufacturers use this method as it can also be done by using injection pressure for low emission starting.

OPERATING MODES continued...

NO_X Control

At any air/fuel ratio greater than the stoichiometric ratio of 14.7:1 (Lambda 1) NO_X gases increase dramatically.
During Port Fuel (Indirect) Injection – Lean Cruise and in DPI Homogeneous Lean Charge Mode, this can be compensated by lowering the combustion temperature with EGR (EGR can be managed by an EGR System or with VCT).
However, this system is only successful with lean mixtures between 14.7:1 (Lambda 1) and 22.8:1 (Lambda 1.55).
To achieve the 60:1 (Lambda 4) that DPI is able to achieve on full Stratified Charge Mode the vehicle requires a downstream NO_X Filter.

The system includes:

- Upstream Wideband Oxygen Sensors
- Catalytic Convertor.
- Exhaust Gas Temp Sensor
- NO_X Filter (also called a NO_X Storage Catalyst)
- NO_X Sensor
- NO_X Sensor Control Module.

Exhaust Gas Temp Sensor

The Exhaust Gas Temp Sensor is used to monitor the exhaust temperature. The NO_X System requires the exhaust gases to be within 250-500°C if the temp exceeds 500°C the engine will return to Homogeneous Charge Mode at 14.7:1.
If the exhaust temp is allowed to exceed 850°C the NO_X Filter will be permanently damaged.

NO_X Filter

The NO_X Filter is essentially of the same construction as a Catalytic Convertor with the addition of a Barium Oxide coating. When the exhaust temp is between 250-500°C the NO_X gases are trapped in the Barium Oxide. When the filter becomes soaked in NO_X (measured by the NO_X Sensor) the engine temporarily returns to a slightly rich Homogeneous Charge Mode to regenerate the NO_X Filter. Unfortunately Sulphur Oxides (SO_X) are very similar to NO_X but require a higher regeneration temperature. This is the reason the Australian market cannot use this System as it only function on fuels with less than 10PPM of Sulphur, Australia currently has up to 50PPM in PULP and up to 150PPM in ULP, E10 & E85.

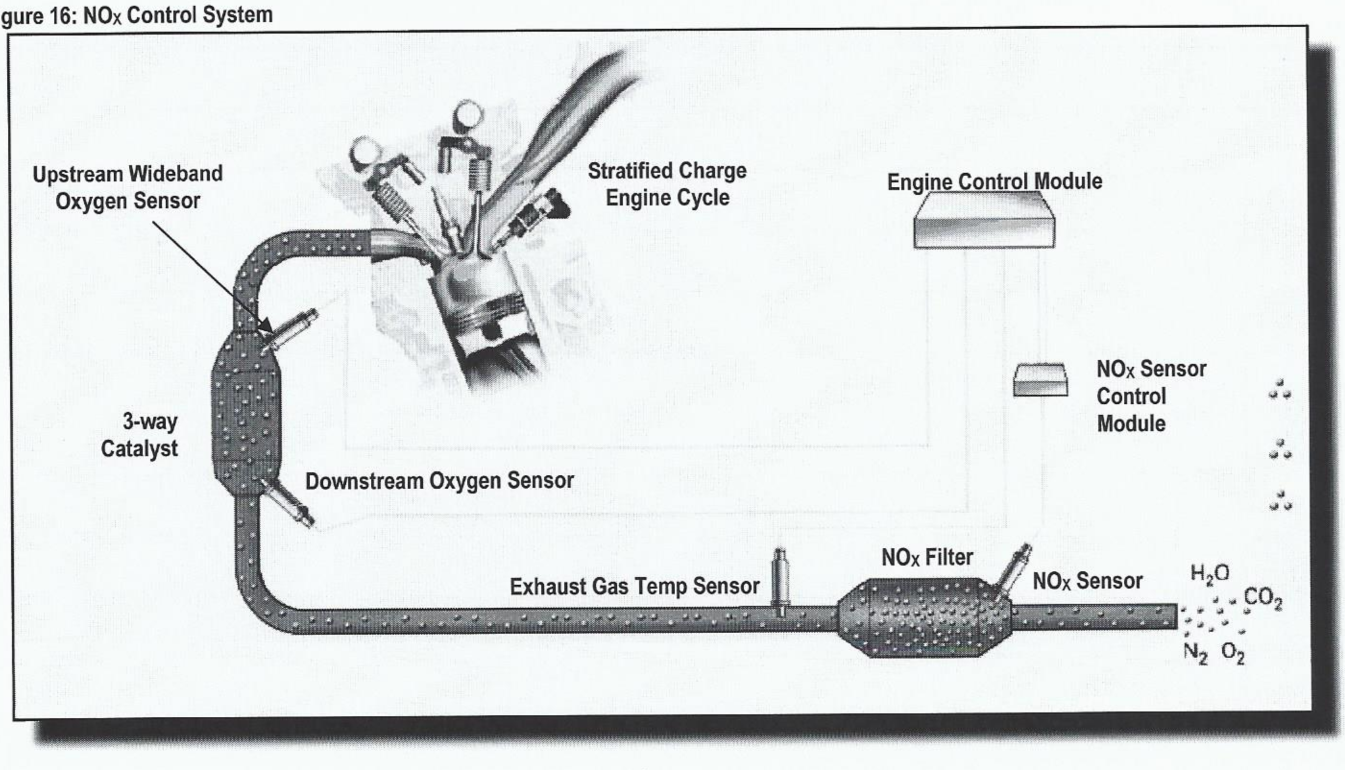
NO_X Sensor

The NO_X Sensor is a Wideband 02 Sensor fitted downstream of the NO_X Filter (it also functions as the Downstream 02 Sensor on some systems). So the exhaust has 4 sensors for each bank Upstream Wideband 02 Sensor > Downstream 02 Sensor > Exhaust Gas Temp Sensor > Downstream NO_X Sensor.

NO_X Sensor Control Module

The NO_X Sensor Control Module can be a stand-alone unit or incorporated into the ECM.

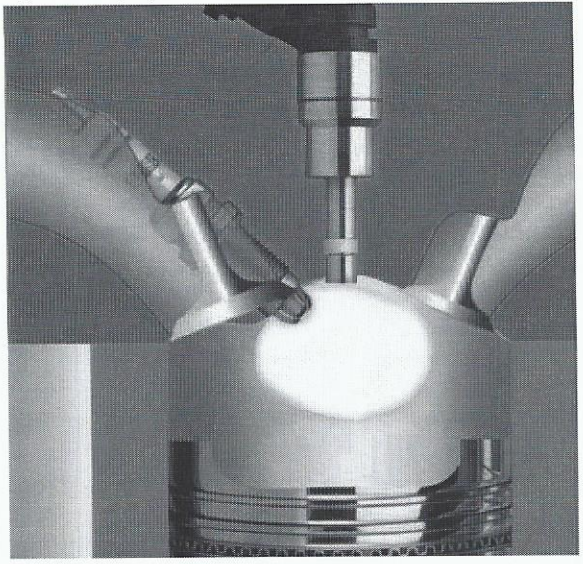
Figure 16: NO_X Control System



DPI CONFIGURATION

There are currently 3 DPI construction configurations that are in use. Each configuration requires its own style of piston crown. You can usually tell which type a vehicle is by the location and angle of the Fuel Injector (gets a bit tricky to pick on V engines). These guiding systems are designed to optimise the Stratified Charge.

Figure 17: Spray Guided

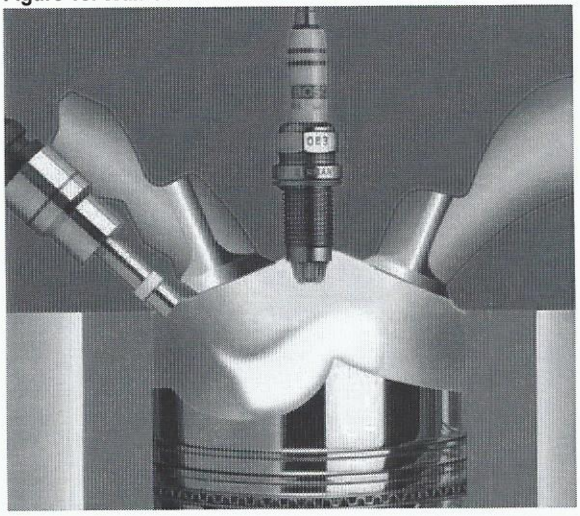


Spray Guided

Construction – Injector points straight down at the top of the piston with the sparkplug electrode located as close as possible to the Injector nozzle.

Function – The Injector sprays the fuel into the desired combustion area.

Figure 18: Wall Guided

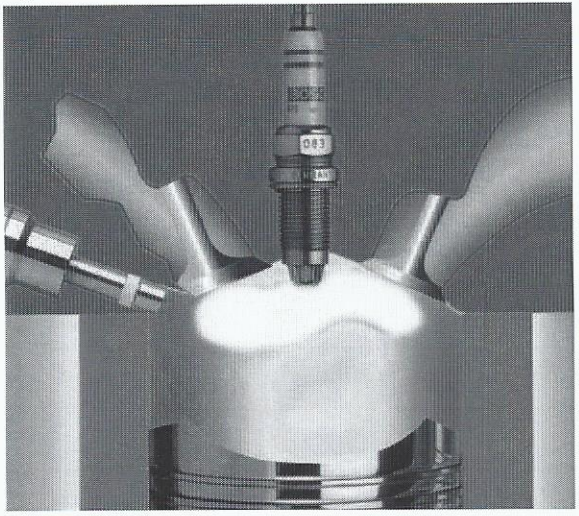


Wall Guided

Construction – Injector points at approx. a 90° angle to the 'Wall' located on the crown of the piston. The Sparkplug is located at the top of the combustion chamber.

Function – The Piston lifts the rich air/fuel mixture into the desired combustion area.

Figure 19: Air Guided



Air guided

Construction – With the Sparkplug located in the top of the combustion chamber and the injector located at nearly 90° to it.

Function – The Injector sprays the fuel into the general area of the Sparkplug. The turbulent air created by the induction system and specially designed piston crown, lifts and holds the rich air/fuel mixture into the desired combustion area.

THE BENEFITS OF DPI

- Increased Volumetric Efficiency
- Cooler Combustion Temp
- Increased Comp Ratio
- Increased Power & Torque From Smaller Engines
- Better Fuel Economy
- Lower Emissions

Note: *These advantages are further enhanced with the coupling of a Variable Compression, Cylinder Shut-off, Variable Valve Timing, Turbocharger, Supercharger and other technologies.*

Safety

Warning: Extremely high fuel pressure (follow safety precautions)

Due to the high fuel pressures used in the DPI systems, extreme care must be taken when servicing and repairs are carried out. When servicing or repairing these systems the technician must ensure that the system controls and holds the high pressures. Below are some points to note: Specific manufacturer's specifications should always be referred to.

Examples of safely decommissioning the high pressure fuel system include:

Depressurising the system using a Scan Tool

or

Waiting for 2 hours after switching the Ignition OFF before opening the high pressure fuel system

and ALWAYS

Wear appropriate Safety Wear (gloves and a face shield)

LOOK FOR THE SYMBOLS THROUGHOUT THE MANUAL

Note: Indicates a point of interest

Caution: Indicates the risk of minor injury, special procedure or possible damage to a component

Warning: Indicates the risk of serious or life threatening injury

Components, Diagnosis & Repairs

The components used in the modern DPI system vary from components that are identical in design and function to that of a typical Port Fuel Injected system, through to components that would previously have been associated with a modern Common Rail Diesel (CRD) system.

This section looks at the components associated with DPI systems from Tank to Injector and from Air Filter to Intake Manifold.
These components include but are not limited to the following:

Fuel System

- Fuel Delivery Unit
- Saddle Style Tanks
- Low Fuel Pressure Sensor
- High Pressure Fuel Pump
- High Pressure Fuel Rail
- High Pressure Fuel Pipes
- Fuel Rail Pressure Sensor
- Fuel Injectors

Intake System

- Mass Air Flow Meter
- Electronic Throttle Body
- Manifold Absolute Pressure (MAP) Sensor
- Variable Intake Manifold
- Brake Booster Vacuum Supply

Included in each of the above sections are up to 4 groups of information. The first group covers all of the standard/generic information about such component. This information is then applied to up to 3 different manufacturers. The vehicles used are identified by their manufacturer's logo and are relevant for the following models:

This image identifies information relevant to one or all of the following:
2005MY Mazda 6 MPS with 2.3L Turbo MZR DISI engine
2006MY Mazda 3 MPS with 2.3L Turbo MZR DISI engine
2006MY Mazda CX-7 with 2.3L Turbo MZR DISI engine

This image identifies information relevant to one or all of the following:
2005MY VW Golf GTi with 2.0L Turbo FSI engine
2006MY VW Jetta with 2.0L FSI engine
2007MY VW Passat with 2.0L Turbo FSI engine
2007MY VW Eos with 2.0L Turbo FSI engine

Note: The VW designed FSI system is also used in turbocharged & naturally aspired configurations by Audi, Seat & Skoda during the same model years (MY).

This image identifies information relevant to one or all of the following:
2010MY VE & WM series I with 3.6L LLT SIDI engine
2010MY VE & WM series II with 3.6L LLT SIDI engine (Flexible Fuel Vehicle)
2010MY VE series I with 3.0L LF1 SIDI engine
2010MY VE series II with 3.0L LFW SIDI engine (Flexible Fuel Vehicle)
2011MY Captiva series II with 3.0L LFW SIDI engine (Flexible Fuel Vehicle)

FUEL SYSTEM

Fuel Delivery Unit

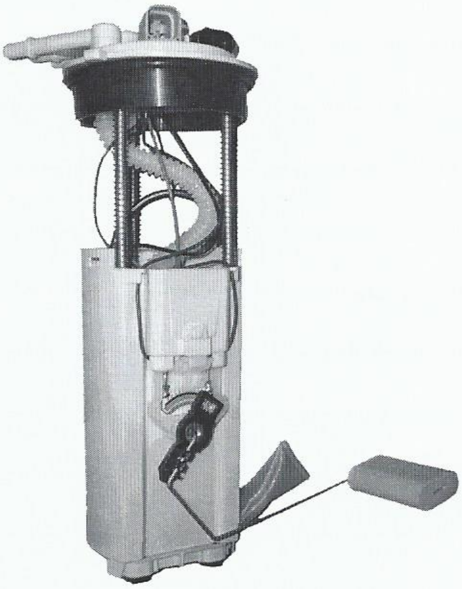


Figure 20: Generic Fuel Delivery Unit

Key features:

- Located in Fuel Tank
- Fuel Level Sender
- Pre-Filter
- Low Pressure Fuel Pump
- Not dissimilar to Port Fuel Injection

In addition to the key features the Mazda 2.3L the Return-less Fuel System also incorporates the Fuel Filter in the Fuel Delivery Unit. It requires replacement every 150,000 km.

Operation:

The Fuel Pump is capable of operating at two speeds. The ECM controls the output of the Fuel Pump by control the power feed to the pump via two relays and a resister. At Idle the power feeds through the resister dropping the voltage under operation to approx. 9 Volts. This helps to reduce the creation of excessive evaporative emissions.

Test Procedure:

To check the Fuel Pressure you must command the Fuel Pump ON with a Scan Tool or follow a manual override procedure.

Fuel Pressure:

410 to 490 kPa (60 to 70 PSI)

Note: *There is a special procedure for refitting the Fuel Delivery Unit into the Fuel Tank which requires it to be tensioned to 110Nm or rotated 620° whichever is greater.*

In addition to the key features the VW FSI the Return-less Fuel System also utilises a variable speed Fuel Pump which is ECM controlled via a Fuel Pump Control Module (FPCM). The FPCM is located in the inspection hole cover, below the rear seat cushion and uses a pulse width modulated signal to control fuel output.

Operation:

The ECM sends Serial Data signals to the FPCM to control Fuel Pump output. The externally mounted Fuel Filter incorporates a Pressure Limiting Valve that will return fuel to the Fuel Tank should a malfunction occur and Fuel Pressure exceeds its limit of 680 kPa (98.6 PSI).

Fuel Pressure:

50 to 500 kPa (7.3 to 72.5 PSI) depending on conditions

Note: *The Fuel Pressure is increased to 650 kPa (94.3 PSI) at start up.*
The ECM also monitors the driver's door switch to predict start up and prime the system.

In addition to the key features the VE SIDI also has an integral Fuel Filter (simular to the Mazda 2.3L) and a FPCM (simular to the VW FSI). The FPCM on the VE SIDI is located on the underside of the Battery Tray in the luggage compartment. Another key difference on the VE SIDI is that the Low Fuel Pressure Sensor is connected directly to the FPCM.

Fuel Pressure:

345 to 414 kPa (50 to 60 PSI)

Note: *Holden do NOT provide a service interval for the Fuel Filter.*

FUEL SYSTEM continued...

Saddle Style Fuel Tanks

With the ever evolving design of the motor vehicle, the position of the fuel tank has had to move into less ideal locations. To gain sufficient fuel storage many manufacturers have had to shift to Saddle Style Fuel Tanks. This allows the Fuel Tank to be moved forward of the rear final drive.

The system requires an addition Fuel Delivery Unit (Module) to transfer fuel from the secondary side of the Fuel Tank.
There are two main methods of transferring the fuel:

- Active
- Suction

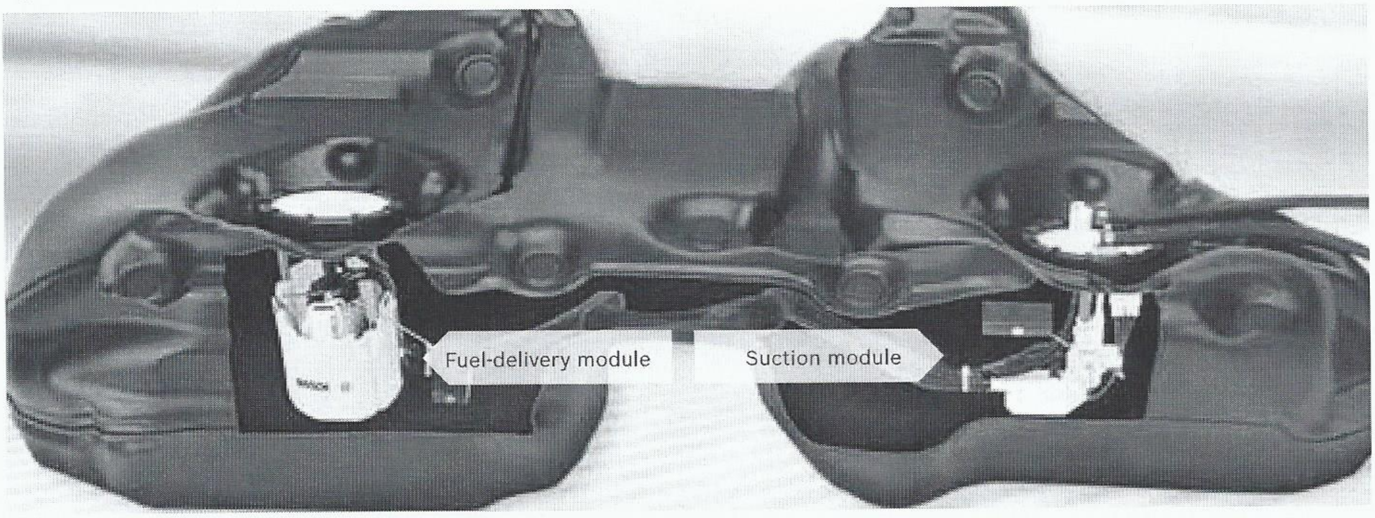
Active

An Active transfer system utilises a second low pressure fuel pump situated on the secondary side of the Fuel Tank. It is ECM controlled based on the values received from the Fuel Level Senders.

Suction

The most popular method is the 'Suction' transfer system, where the low pressure created at the Secondary Fuel Pump incorporated into the Primary Fuel Delivery Unit. Any extra fuel pumped across while the tank is in the upper level of its storage simply spills back into the secondary side of the Fuel Tank.

Figure 21: Saddle Style Fuel Tank with Secondary Suction Unit



The Saddle Style Fuel Tank used in the VE is very similar to the one pictured above and utilises a Suction Type system.

Note: *On VE models, to gain access to the Fuel Delivery Unit and/or the Secondary Suction Unit you must first remove the Fuel Tank.*

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FUEL SYSTEM continued...

Low Fuel Pressure Sensor

The ECM monitors the pressure in the low side of the fuel supply for feedback in control of the Fuel Pump. It can alter the fuel pressure to resist air locks in extremely high temperatures. It is also used for fault diagnosis. In general these sensors are of the same design and operation as those used on Port Fuel Injection systems.

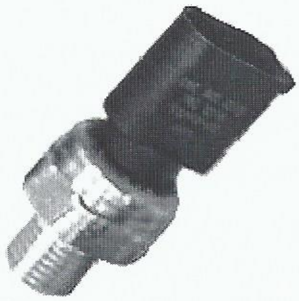


Figure 22: VW 2.0L FSI Low Fuel Pressure Sensor

The VW FSI Low Fuel Pressure Sensor is located on the High Pressure Fuel Pump.

Mazda do not use a Low Fuel Pressure Sensor. Switching from low to high output is based solely on idle status.

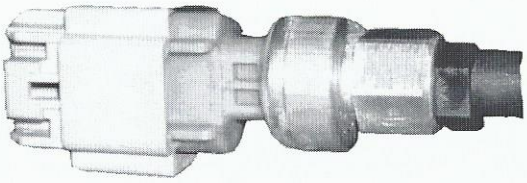


Figure 23: VE SIDI Low Fuel Pressure Sensor

On the VE SIDI the Low Fuel Pressure Sensor is located alongside the Fuel Tank.
It is connected to the FPCM, which converts the value into Serial Data and transmits it over the GM LAN Serial Data Network.

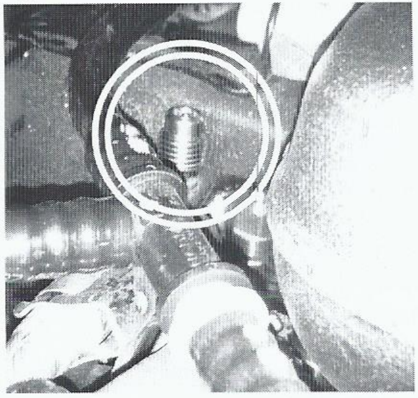
Operation:
The fuel pressure sensor is a three wire Piezo-resistive unit with a five volt supply, reference low and a signal circuit that is pulled low.

Low Fuel Pressure Test Point

For most DPI vehicles it is possible to test the low fuel pressure system. The procedures vary and resemble methods used in Port Fuel Injection systems

Both the 3.0L and 3.6L engine have a Low Pressure Service Port provided on the right rear corner of the engine. For the 3.0L it is mounted to the back of the right back Cylinder Head, while the 3.6L is behind the right rear corner of the Intake Manifold (*see Figure 24*)

Figure 24: VE 3.6L SIDI Service Port



Both the Mazda 2.3L DISI and the VW 2.0L FSI systems require the inline installation of a fuel pressure gauge.

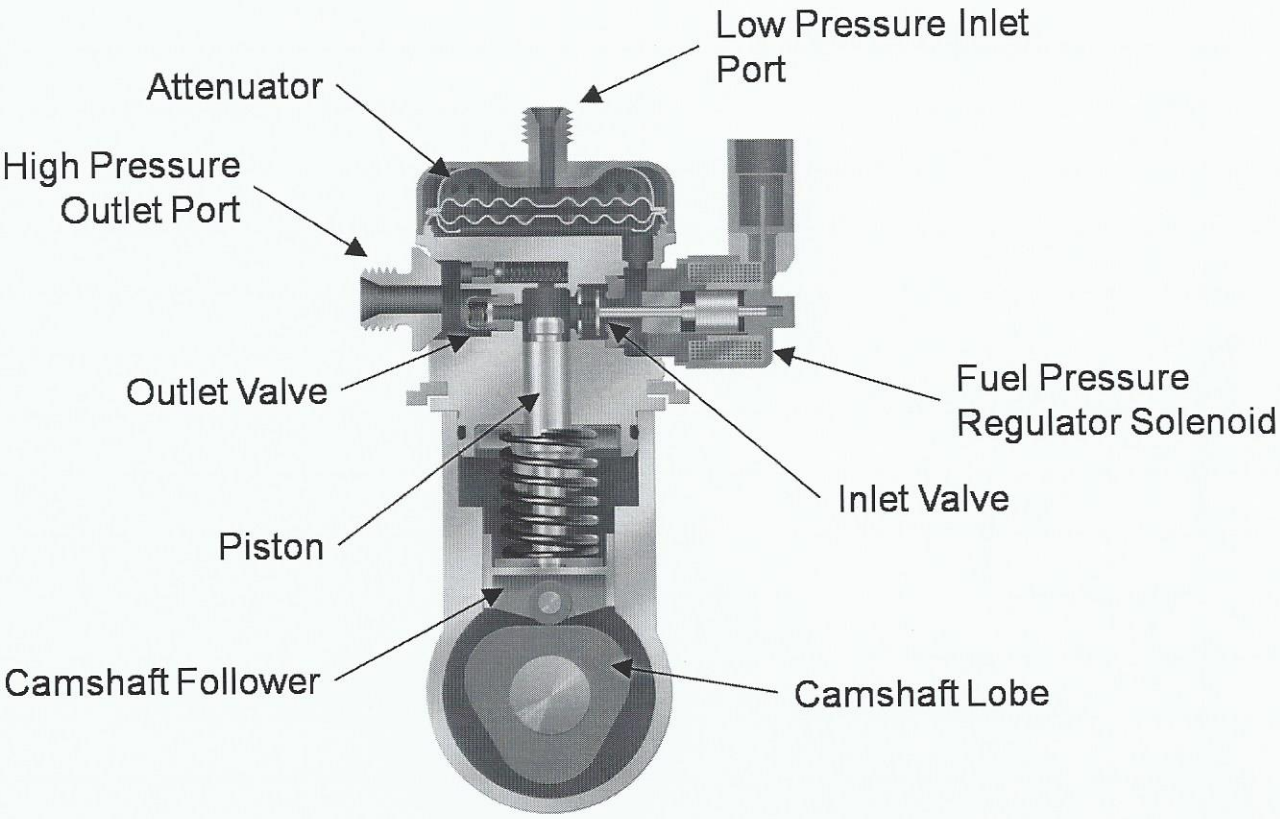
Note: Fuel Pressure Test Procedures and Fuel Pressures are provided with the Fuel Delivery Unit details on Page 33.

FUEL SYSTEM continued...

High Pressure Fuel Pump

The mechanically driven High Pressure Fuel Pump is in most, if not all circumstances driven from the camshaft. The configurations alter slightly from manufacturer to manufacturer but the elements of the pump are consistent. *Figure 25* shows the elements of a generic High Pressure Fuel Pump.

Figure 25: High Pressure Fuel Pump construction



Elements of a High Pressure Fuel Pump (HPFP)

Low Pressure Inlet port

Fuel is fed to the from the Low Pressure Fuel Pump located in the Fuel Delivery Unit

Fuel Pressure Regulator

The Fuel Pressure Regulator consists of an ECM controlled solenoid which opens and closes the Fuel Pressure Regulator Inlet Valve, controlling the fuel supply to the HPFP with the consequence of controlling the output fuel pressure.

Attenuator

The Attenuator absorbs fluctuation in the fuel supply caused by the operation of the Fuel Pressure Regulator.

Piston

Driven from the Camshaft, the Piston creates the pressure in the Pump Chamber.

Camshaft

The lobes on the Camshaft actuate the Piston. The number of lobes varies from 2 to 4 depending on application (often assumed that there is 1 lobe for each pair of cylinder, this is NOT the case).

Camshaft Follower

The Camshaft Follower provides a low friction connection between the Camshaft and the Piston. The Follower illustrated in *Figure 25* utilises a roller, some systems use a static Follower.

Outlet Valve

The Outlet Valve functions as a non-return (check) valve, only letting fuel to travel from the HPFP to the Fuel Rail.

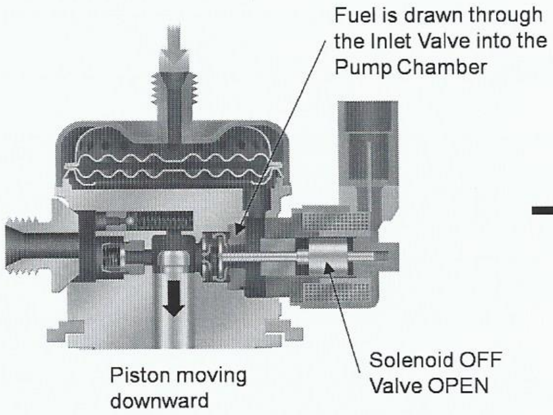
FUEL SYSTEM continued...

High Pressure Fuel Pump operation

The operation cycle of the HPFP consists of 3 strokes:

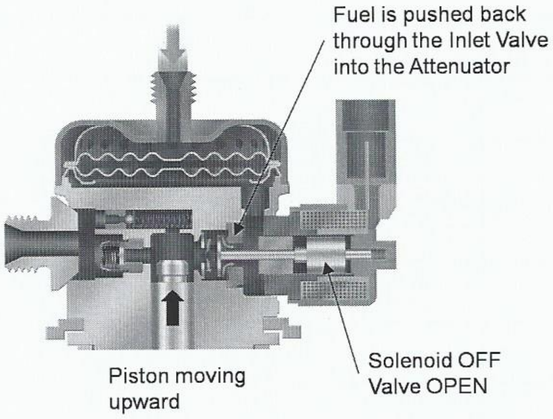
- Intake
- Return
- Delivery

Figure 26: Intake Stroke


Fuel is drawn through the Inlet Valve into the Pump Chamber
Piston moving downward
Solenoid OFF Valve OPEN

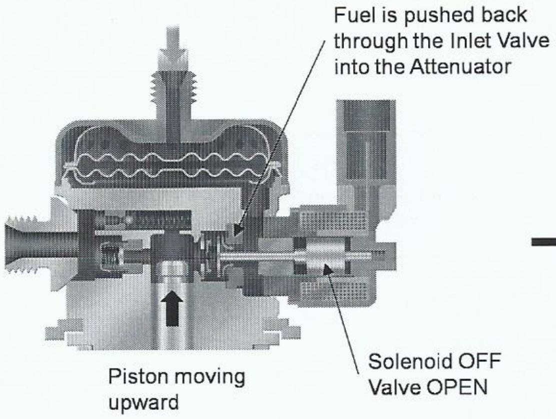
The Pump Piston moves downward with the rotation of the Camshaft. Because the Regulator Control Solenoid is NOT energised by the ECM the Inlet Valve is OPEN. The low pressure created in the Pump Chamber is now lower than the fuel in the low pressure system and fuel is drawn into the Pump Chamber.

Figure 27: Return Stroke


Fuel is pushed back through the Inlet Valve into the Attenuator
Piston moving upward
Solenoid OFF Valve OPEN

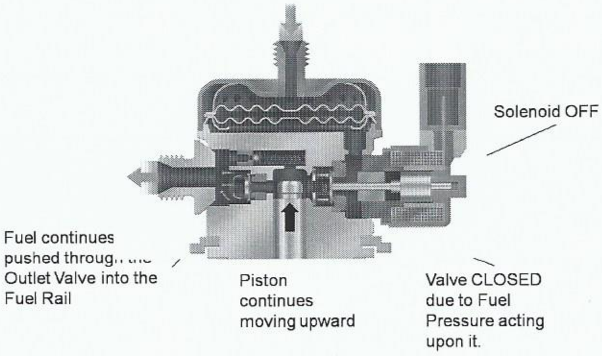
The Pump Piston now moves upward with the rotation of the Camshaft. Because the Regulator Control Solenoid is still NOT energised by the ECM the Inlet Valve remains OPEN. The pressure created in the Pump Chamber is not enough to open the Outlet Valve and the fuel is pushed back through the Inlet Valve into the Attenuator. The Attenuator absorbs the returning fuel ready for the next Intake Stroke.

Figure 28: Delivery Stroke - Part 1


Fuel is pushed back through the Inlet Valve into the Attenuator
Piston moving upward
Solenoid OFF Valve OPEN

The Pump Piston continues moving upward with the rotation of the Camshaft. The Regulator Control Solenoid is energised by the ECM and the Inlet Valve is CLOSED. The pressure created in the Pump Chamber forces the Outlet Valve to open and the fuel is delivered to the Fuel Rail.
The ECM knows the position and the direction of travel for the Pump Piston thanks to the Camshaft Position Sensor. It uses this information along with the Fuel Rail Pressure Sensor and various other sensors to maintain the desired pressure in the Fuel Rail, through control over the Regulator Control Solenoid.

Figure 29: Delivery Stroke - Part 2


Solenoid OFF
Fuel continues pushed through the Outlet Valve into the Fuel Rail
Piston continues moving upward
Valve CLOSED due to Fuel Pressure acting upon it.

The Pump Piston continues moving upward as it approaches the peak of the Camshaft Lobe. The ECM de-energises the Regulator Control Solenoid. However due the force of the fuel pressure acting on the back of the Inlet Valve it remains CLOSED and the fuel continues to be delivered to the Fuel Rail. This method of operation allows the Solenoid time to stabilise before it is re-energised by the ECM.

FUEL SYSTEM continued...

High Pressure Fuel Pump application

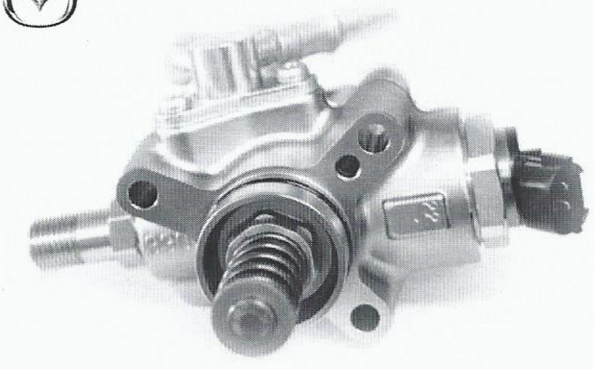


Figure 30: Mazda 2.3l DISI - HPFP

Features:

- 3 lobe camshaft drive
- Pulse Width Modulated ECM control

Scan Tool Data:

@ Idle = 3,000 kPa
@ 60% Load =11,500 kPa

Caution: The outlet union must be held firmly with a spanner while loosening and tightening the High Pressure Pipe. If it is allowed to move even the smallest amount the integrity of the high pressure fuel connection cannot be assured and Mazda states that the High Pressure Pump MUST be replaced.

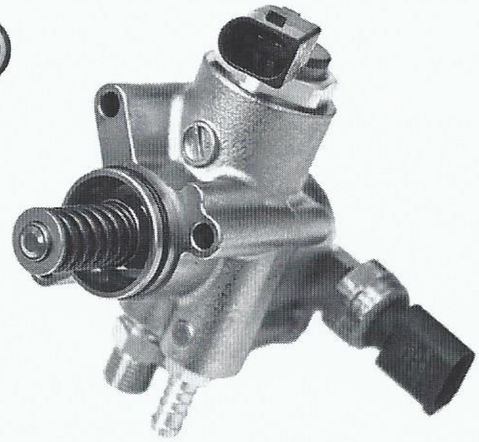


Figure 31: VW 2.0L FSI - HPFP

Features:

- 2 lobe camshaft drive
- Incorporates Low Fuel Pressure Sensor
- Pulse Width Modulated ECM control

Scan Tool Data:

Range = 3,100 to 11,000 kPa

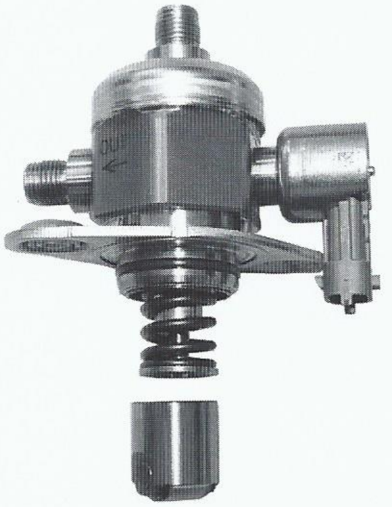


Figure 32: VE SIDI - HPFP

Features:

- 3 lobe camshaft drive
- Roller Type Camshaft Follower
- Pulse Width Modulated ECM control

Scan Tool Data:

3.0L LF1 & LFW engines = 2,000 to 15,000 kPa
3.6L LLT engine = 3,000 to 12,000 kPa

Special Service Tools (SST's) required:

- EN-488896 – HPFP installer

Caution: The High Pressure Fuel Pipes are a Single Use item. If loosened for ANY reason they MUST be replaced!

Warning: Extremely high fuel pressure (follow safety precautions)

FUEL SYSTEM continued...

High Pressure Fuel Rail

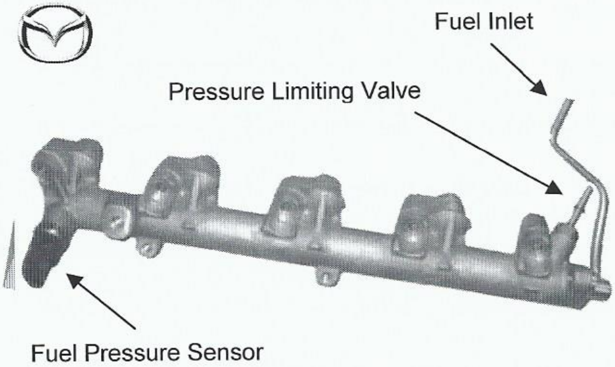

Fuel Inlet
Pressure Limiting Valve
Fuel Pressure Sensor

Figure 33: Mazda 2.3l DISI – Fuel Rail

Features:

- Aluminium construction
- Pressure Limiting Valve
-

Caution: Mazda states that the Fuel Rail Pressure Sensor MUST NOT be removed from the Fuel Rail. If the sensor is diagnosed as faulty the Fuel Rail Assembly must be replaced.

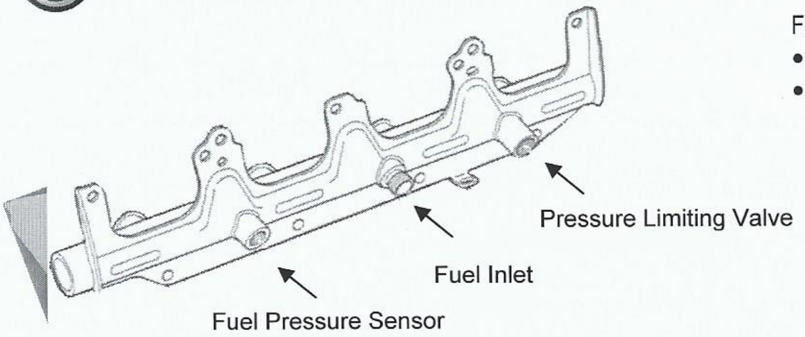

Pressure Limiting Valve
Fuel Inlet
Fuel Pressure Sensor

Figure 34: VW 2.0L FSI – Fuel Rail

Features:

- Stainless Steel construction
- Pressure Limiting Valve limits pressure during malfunction to 12,000 kPa

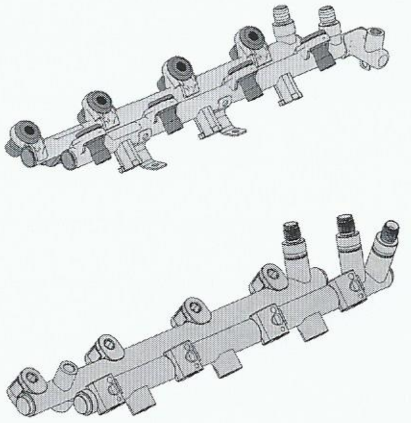


Figure 35: VE SIDI – Fuel Rails (TOP: 3.0L - BELOW: 3.6L)

Features:

- Stainless Steel construction
- 3.0L – 2 x pipe fittings at the rear
- 3.0L – 1 x sensor fitting at the rear
- 3.6L – 3 x pipe fittings at the rear
- 3.6L – 1 x sensor fitting at the front

Caution: The High Pressure Fuel Pipes are a Single Use item. If loosened for ANY reason they MUST be replaced!

Warning: Extremely high fuel pressure (follow safety precautions)

FUEL SYSTEM continued...

High Pressure Fuel Pipes

The High Pressure Fuel Pipes connect the HPFP to the Fuel Rail and in some V construction engine they also connect the Fuel Rails of each cylinder bank together.

The seal where each joint seals MUST be able to withstand fuel pressure in excess of 15,000 kPa (2176 PSI). For this reason a number of manufacturers state that the High Pressure Fuel Pipes are single use and MUST NOT be reused. Of the vehicle highlighted in this Technical Training Manual the Holden vehicles have this requirement, the following information highlights why.

VE SIDI single use High Pressure Fuel Pipes

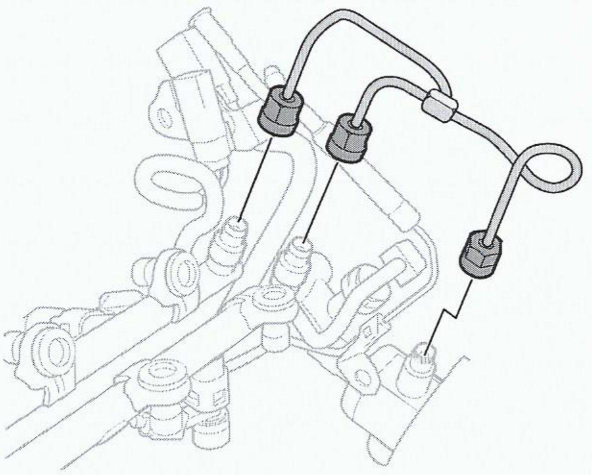


Figure 36: VE 3.0L (LF1 & LFW) High Pressure Fuel Pipes

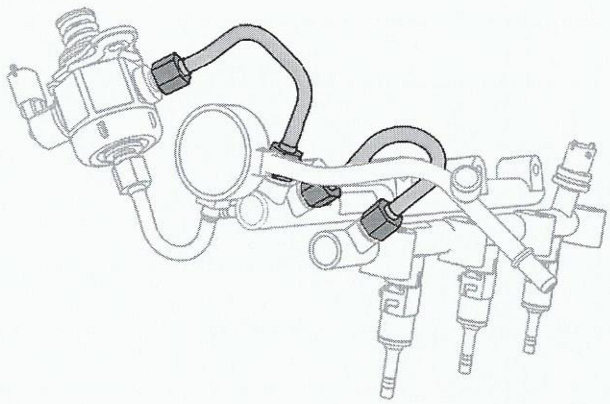
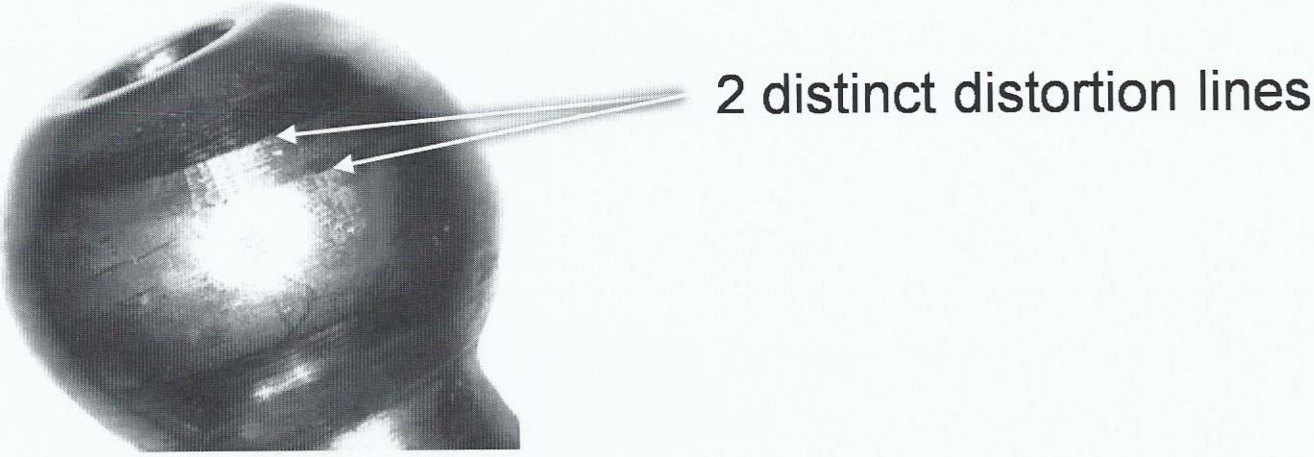


Figure 37: 3.6L (LLT) High Pressure Fuel Pipes

When the flange nuts on the High Pressure Fuel Pipes are tightened the ball flare on the end of the pipe crushes to create the seal required to withstand the high fuel pressures. *Figure 38* shows clearly the distortion lines created once crushed. It is impossible to refit the pipes to the exact location and even if it were possible because the ball flare has already distorted the high pressure connection will be severely compromised.

Figure 38: Close up of VE SIDI High Pressure Fuel Pipe fitting



Caution: The High Pressure Fuel Pipes are a Single Use item. If loosened for ANY reason they MUST be replaced!

Warning: Extremely high fuel pressure (follow safety precautions)

FUEL SYSTEM continued...

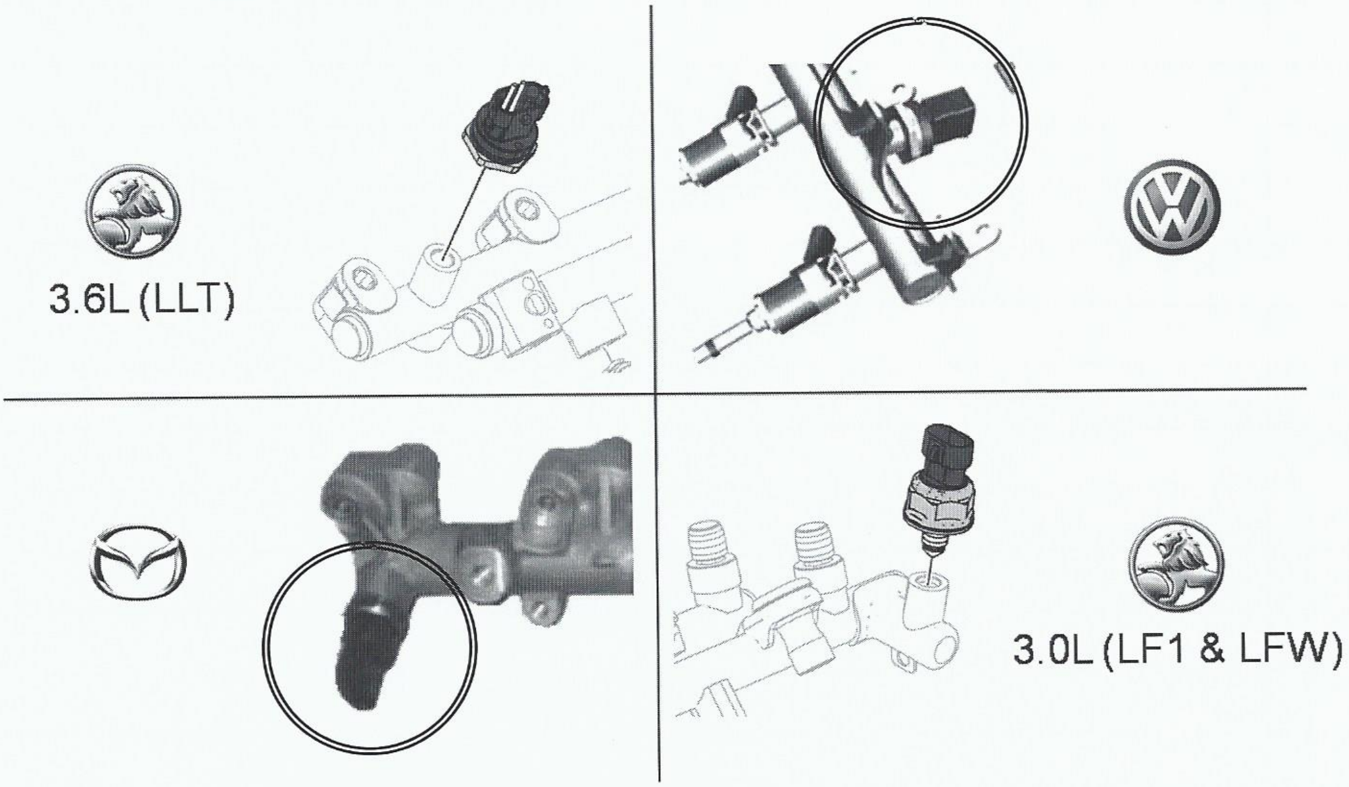
Fuel Rail Pressure Sensors

The Fuel Rail Pressure Sensors are usually located on the Fuel Rail however it is possible for them to be mounted anywhere between the HPFP outlet and the Fuel Rail.

The sensing unit employs a thin metal membrane that is distorted under pressure.

The Engine Control Module (ECM) provides a 5 volt reference voltage on the 5 volt reference circuit and ground on the low reference circuit. The ECM receives a varying signal voltage on the signal circuit. When the fuel pressure is high, the signal voltage is high. When the fuel pressure is low, the signal voltage is low.

Figure 39: Fuel Rail Pressure Sensors and their locations



⚠ *Caution:* *Mazda states that the Fuel Rail Pressure Sensor MUST NOT be removed from the Fuel Rail. If the sensor is diagnosed as faulty the Fuel Rail Assembly must be replaced.*

⚠ *Caution:* *Holden states that the High Pressure Fuel Pipes are a Single Use item. If loosened for ANY reason they MUST be replaced!*

⚠ *Warning:* *Extremely high fuel pressure (follow safety precautions)*

FUEL SYSTEM continued...

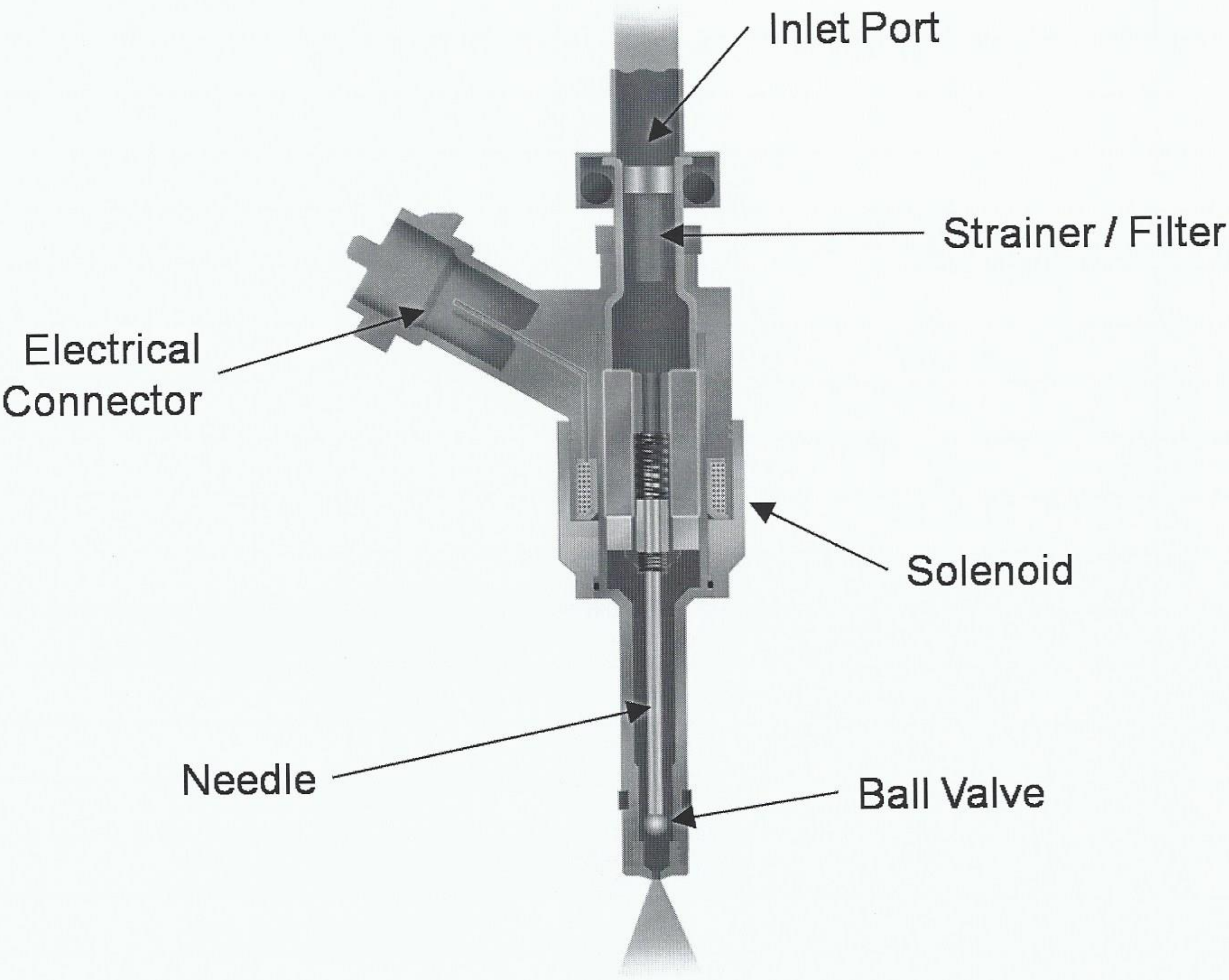
Fuel Injector Design

While the principle design of the DPI Fuel Injector is not unlike that of a Port Fuel Injected engine, the environment and conditions under which it operates are somewhat different. *Figure 40* shows the main components of a generic DPI Fuel Injector.

A key attribute that improves the performance of DPI Fuel Injectors is the high pressure fuel supply. With the assistance of a High Voltage injector trigger the injectors produces a finely atomised and precise charge of fuel directly into the combustion chamber.

Owing to these improvements the DPI Fuel Injector is noticeably noisier than those of a Port Fuel Injected system.

Figure 40: Generic DPI Fuel Injector



Key Features:

- Fitted directly into the Combustion Chambers
- Up to 100 Volts to open
- Battery Volts to hold open
- Require SST's to remove and replace
- Cleanable & Testable
- NOT repairable

Warning: Extremely high fuel pressure (follow safety precautions)

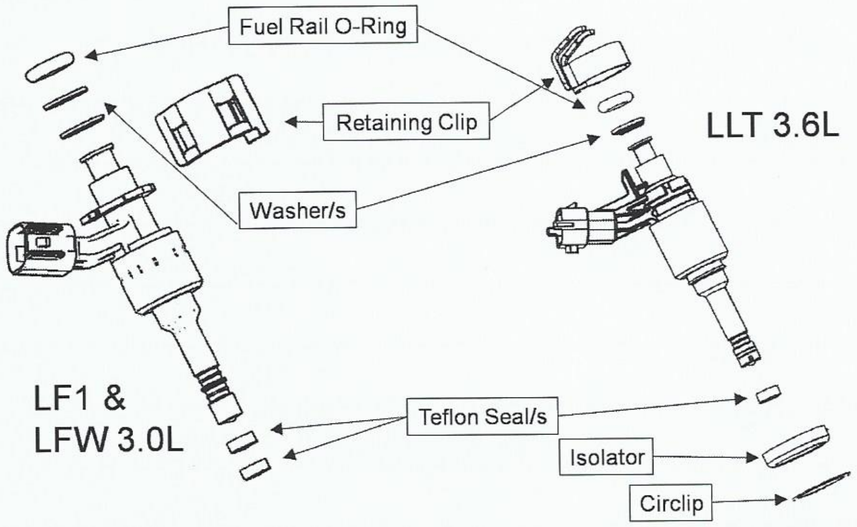
FUEL SYSTEM continued...

VE SIDI Fuel Injectors

General Description

Although they perform the same task the Fuel Injectors for the 3.0L and 3.6L VE SIDI engines vary dramatically in their fitting design. Holden have gone to great lengths to try and muffle the noise generated by the DPI Fuel Injectors, stuffing insulation around the Intake Manifold and the Fuel Rail and Injectors.

Figure 41: VE SIDI Fuel Injectors



3.0L (LF1 & LFW) Features

In addition to the key features of the generic DPI Fuel Injector, the Hitachi Fuel Injectors used in the 3.0L VE SIDI feature:

- Dual Teflon Combustion Chamber Seals
- Fuel Injectors are mounted into the Fuel Rail before being installed into the Cylinder Head.

Special Service Tools (SST's) required:

- EN-47909 Injector Bore and Sleeve Cleaning Kit
- EN-49245 Fuel Injector Seal Install and Sizer
- EN-49247 Injector Retaining Clip Installer
- EN-49248 (x2) Injector Rail Remover

3.6L (LLT) Features

In addition to the key features of the generic DPI Fuel Injector, the Bosch Fuel Injectors used in the 3.6L VE SIDI feature:

- Single Teflon Combustion Chamber Seal
- An Isolator which function as a spring and allow the Fuel Injector to move slightly in the Cylinder Head assisting in noise reduction.

Special Service Tools (SST's) required:

- EN-47909 Injector Bore and Sleeve Cleaning Kit
- EN-48266 Fuel Injector Seal Install and Sizer
- J-37281-A Injector Remover

Operation

The ECM's control of both the 3.0L and 3.6L system is very simular:

- 60 Volt opening signal
- Battery Volts Pulse Width Modulated (PWM) holding (on-time) signal.

The adoption of Pulse Width Modulated holding signal owes to the low resistance (1.25 to 1.75 Ohms) of the Injector Coil.

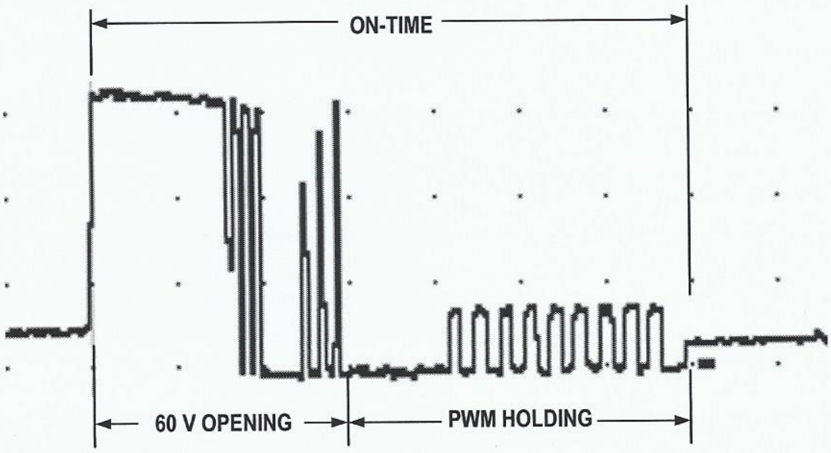


Figure 42: Scope image of Injector Control

FUEL SYSTEM continued...

Mazda 2.3L DISI Fuel Injectors

General Description

Unlike the Bosch Fuel Injectors used in the 3.6L VE SIDI the Bosch Fuel Injectors used in the Mazda DISI do not use Teflon seal but instead rely upon a spring tension metal composite gasket.

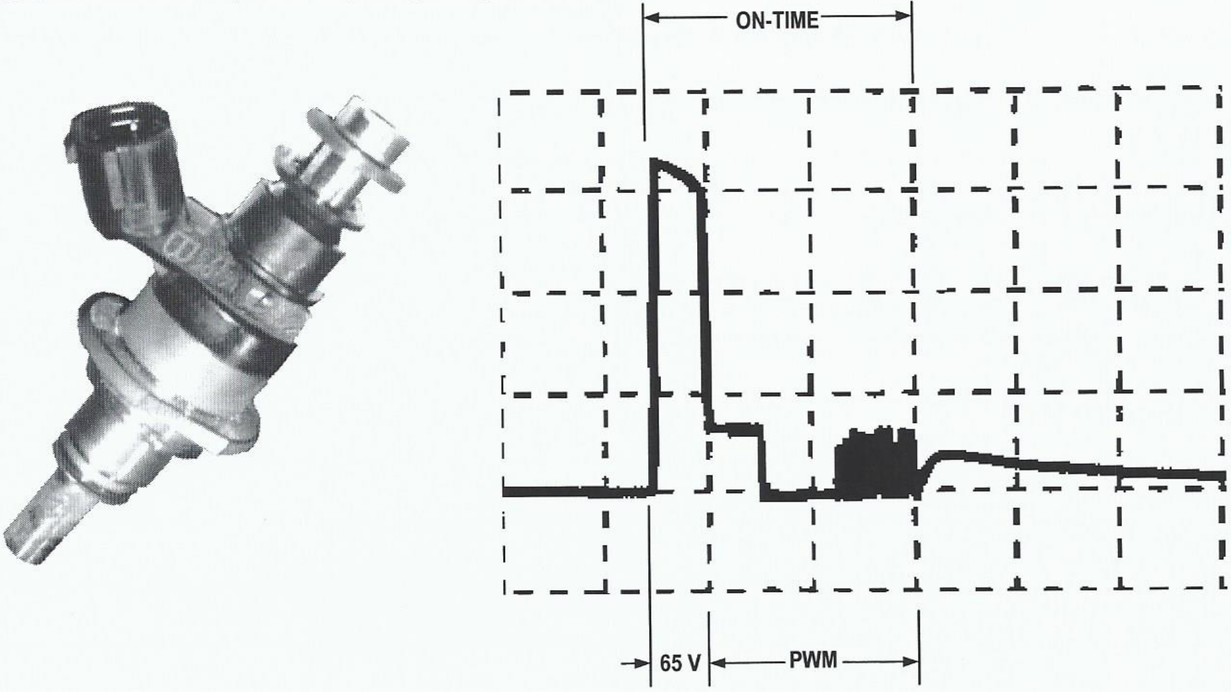
Operation

Similar to the VE SIDI:

- 65 Volt opening signal
- Battery Volts Pulse Width Modulated (PWM) holding (on-time) signal.

The adoption of Pulse Width Modulated holding signal owes to the low resistance (1 to 1.2 Ohms) of the Injector Coil.

Figure 43: Mazda DISI Fuel Injector & Scope image of Injector Control



Removal & Replacement

A Special Service Tool (SST 49-G013-101 seen in *Figure 44*) is required to extract the Fuel Injector.

1. With the SST in place, twist the injector from side to side until it is free
2. No.3 Fuel Injector does not have sufficient room to twist without fowling on the Crankcase Ventilation Oil Separator.
3. To overcome this cut the corner off the upper tab as seen in *Figure 45*.
4. After all of the injectors have been removed, use a vacuum hose to remove carbon particles from the top of the piston.
5. Oil the gasket & O-ring before installation.

Figure 44: Mazda DISI - SST

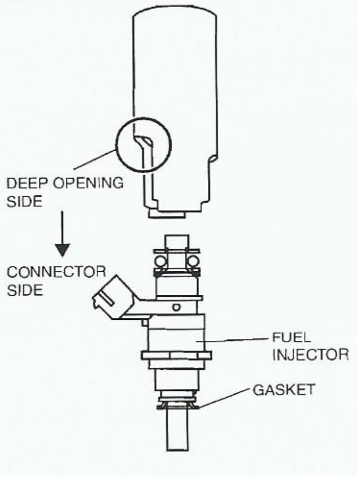
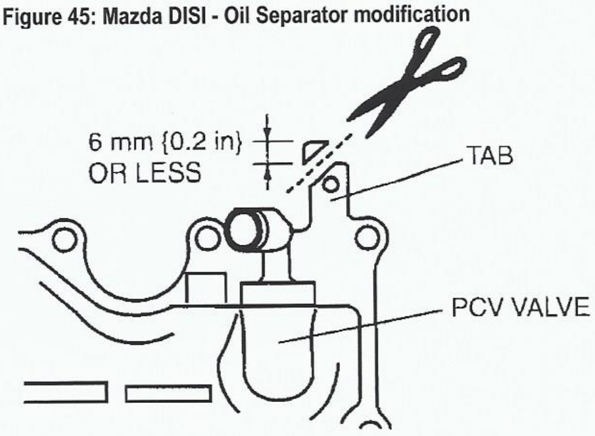


Figure 45: Mazda DISI - Oil Separator modification



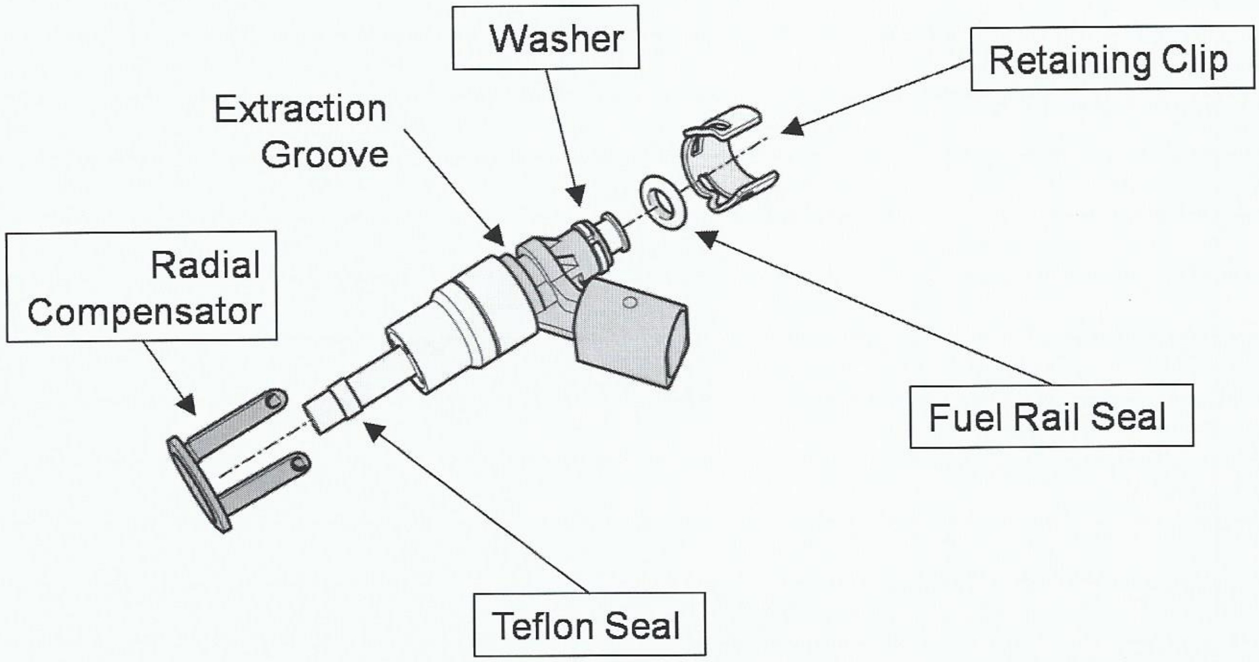
FUEL SYSTEM continued...

VW 2.0L FSI Fuel Injectors

General Description

Similar to the Bosch Fuel Injectors used in the 3.6L VE SIDI the Bosch Fuel Injectors used in the VW FSI use a Teflon seal.

Figure 46: VW 2.0l FSI - Fuel Injector



Note: Items that have a boxed name are the serviceable components.

Operation

Unlike the previous two systems, VW rely on higher voltage and a greater current load to operate the Fuel Injectors without using a Pulse Width Modulated holding signal.

- 90 Volt at up to 10 Amps opening signal.
- Up to 30 Volts at 3-4 Amps holding signal

Injector resistance = 0.5 to 2.0 Ohms

Special Service Tools (SST's) required:

- **T10133 – Fuel Injector Service Kit**
- T10133/1 – Double Jaw Puller
- T10133/2 – U Shaped Puller
- T10133/3 – Slide Hammer
- T10133/4 – Bore Brush
- T10133/5 – Taper Tool
- T10133/6 – Taper Tool Sleeve
- T10133/7 – Seal Adapter
- T10133/8 – Seal Adapter
- T10133/9 – Injector Installer

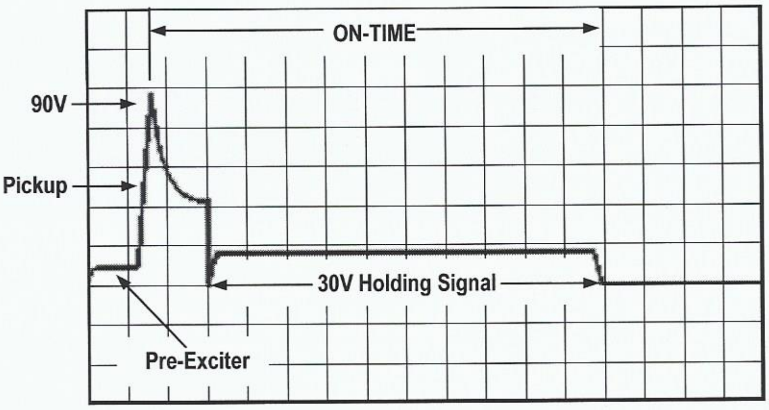


Figure 47: Scope image of Injector Control

Removal & Replacement

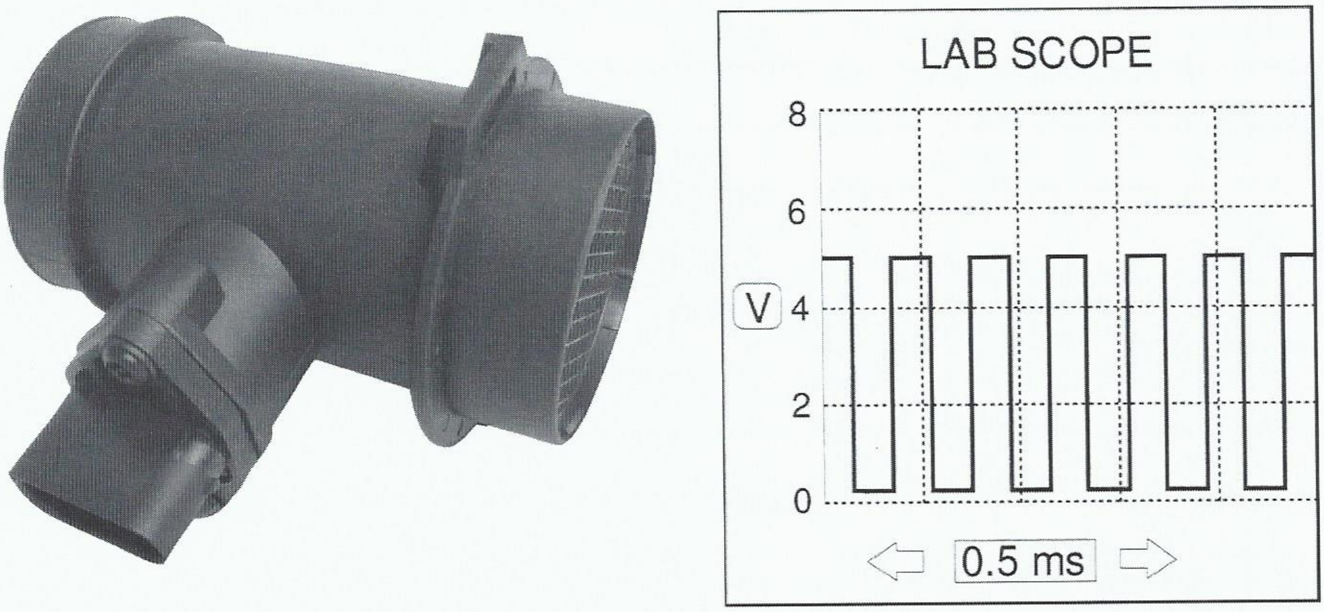
To remove and replace the Fuel Injectors:

1. Break tags off of the Radial Compensator with a screw driver (taking care not to damage the injector)
2. Fit the inner then outer Injector Clamps
3. Attach the slide hammer and gently extract the injector.
4. Remove the seals and clean the Injector
5. Use the relevant Seal Installers to fit the seals
6. Clean the Injector mounting hole in the Cylinder Head with the brush provided
7. Push the injector into the Cylinder Head with the Installer ensuring that the connector is facing the right direction.

INTAKE SYSTEM

Mass Air Flow Meter

Figure 48: Generic Mass Air Flow Meter and typical lab scope output



The hot film type Mass Air Flow Meters use a sensing element encapsulated in glass. They are capable of outputting both analogue and digital signals, however most DPI systems utilise the latter.
The electronic circuits and the sensor element of the Mass Air Flow Meter are accommodated in a compact plastic housing. The Intake Air Temp Sensor sits to the side of the sensor. The sensor can also measure reverse air flow, this allows for a more accurate reading of incoming air. In the event of a failure of the sensor the engine will still run although the idle may be higher.

Located at the lower end of the housing is a metering duct, into which the sensor element projects.
The Scan Tool Data reading is usually output in Grams per Second (g/s).

Intake Air Temperature Sensor

The intake air temp signal is used as a correction value for the Mass Air Flow Meter, as the temperature of the air affects its density. The Intake air Temp Sensor is usually integrated into the Mass Air Flow Meter, however many systems that utilise a Turbocharger or Supercharger employ a second Intake Air Temp Sensor on the Intake Manifold for correction after the air has been charged.

INTAKE SYSTEM continued...

Electronic Throttle Body

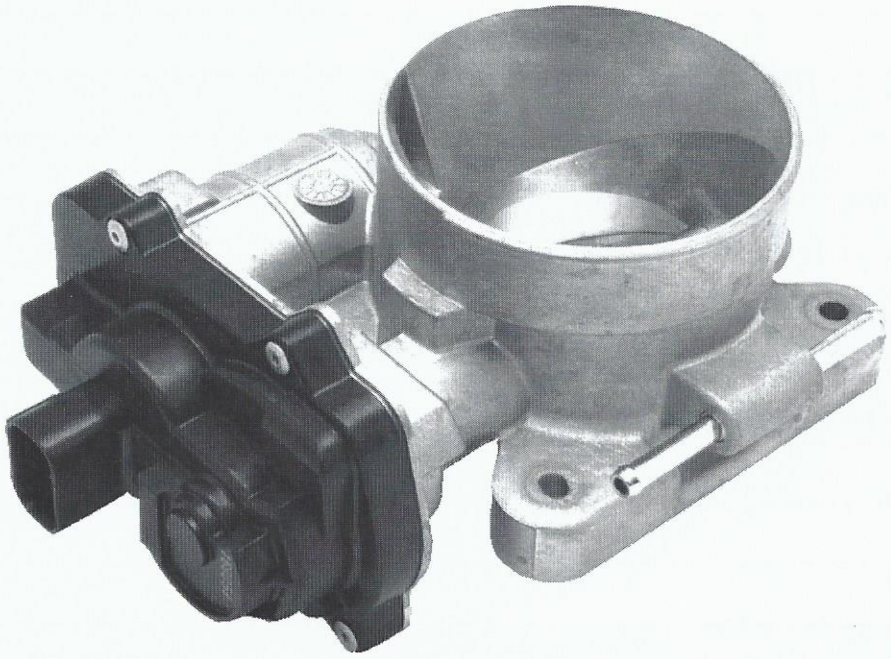


Figure 49: Generic Throttle Body

Description

While the construction of the Electronic Throttle Body is not dissimilar to that of a Port Fuel Injection vehicle, it is now used in a different manner by the ECM.

Function

The ECM's control over the Throttle Plate varies depending on the Charge Mode:

Homogeneous Charge Mode:

In Homogeneous Charge Mode the throttle works in a similar manner to that of a Port Fuel Injection vehicle.

Homogeneous Lean Charge Mode:

In Homogeneous Lean Charge Mode the Throttle Plate is held at a greater angle than Homogeneous Charge Mode which has a number of benefits

- Reduced restriction on air being drawn into the cylinder
- Improved scavenging creating greater volumetric efficiency
- Leaner air/fuel ratio

It does however have some negative aspects which need to be overcome:

- The loss of intake manifold vacuum means that the Brake Booster requires a Vacuum Pump (simular to diesel vehicles).
- The loss of intake manifold vacuum also affect when EGR can occur, this is where the Manifold Absolute Pressure (MAP) Sensor comes into play.

Stratified Charge Mode:

When operating in Stratified Charge Mode the operation of the Throttle Plate becomes very different.
In Stratified Charge Mode the Throttle Plate remains fully open for most of the time and only closes slightly when EGR is required (again, very similar to the operation of a diesel vehicle).
In this situation engine output is governed solely on fuel injection quantity.
This further enhances the benefits & negative aspects listed for Homogeneous Lean Charge Mode.

Note: *The graph (Figure 50) on the next page provides a graphical example of the operation on the Throttle Plate in different Charge Modes.*

INTAKE SYSTEM continued...

Electronic Throttle Body Operation

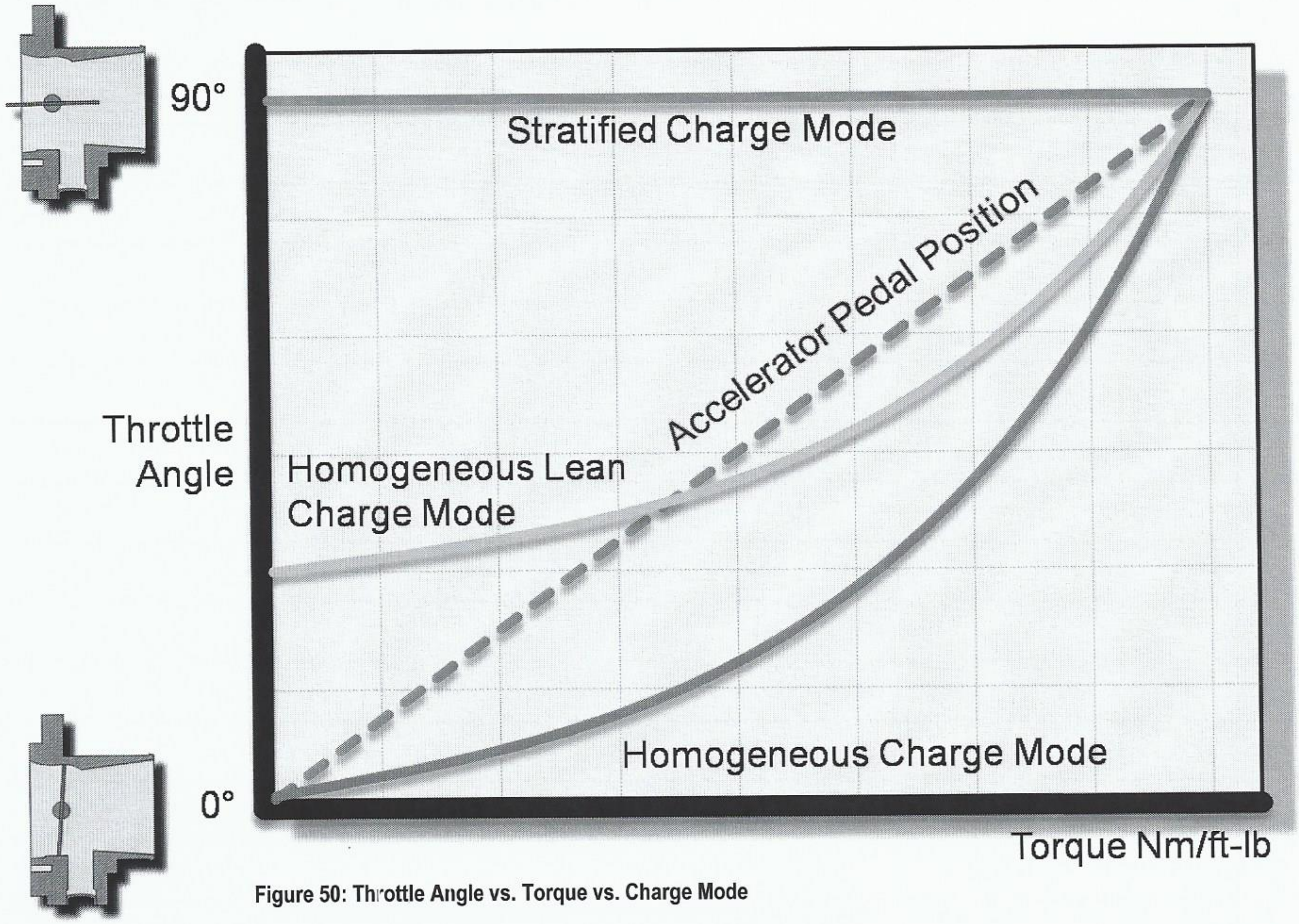


Figure 50: Throttle Angle vs. Torque vs. Charge Mode

INTAKE SYSTEM continued...

Manifold Absolute Pressure (MAP) Sensor

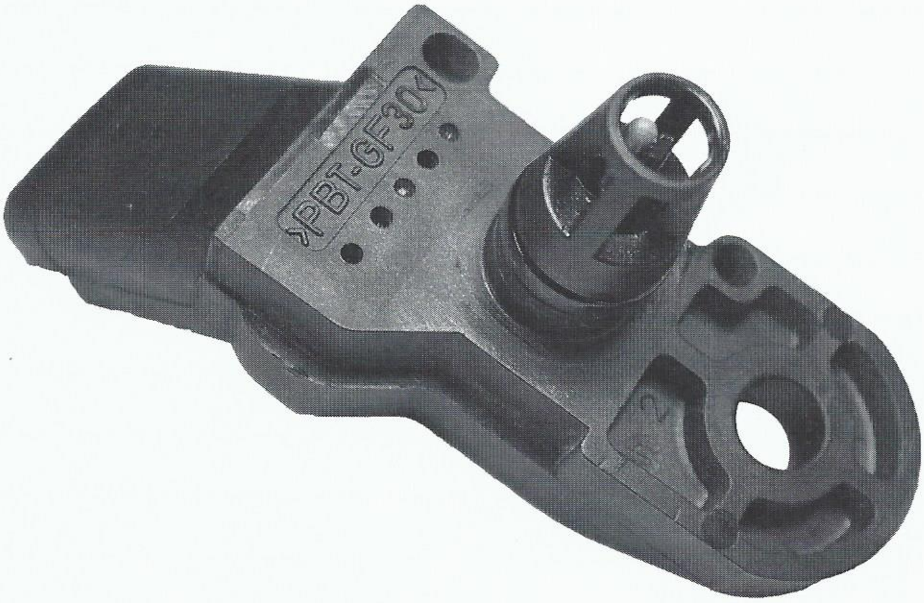


Figure 51: MAP Sensor with Intake Air Temp Sensor

Description

The MAP Sensor is a Piezo-electric device which measures changes in Manifold Pressure. They are capable of outputting both analogue and digital signals, however most DPI systems utilise the latter.

Function

Although the design of the MAP Sensor is identical in DPI as in Port Fuel Injected systems, what is different is its Function.
For the most part it is no longer used as part of the Fuel Control System, it has 2 key functions:

1. To monitor the amount of intake manifold vacuum so that the ECM can determine when to carry out EGR
2. For diagnostic purposes.

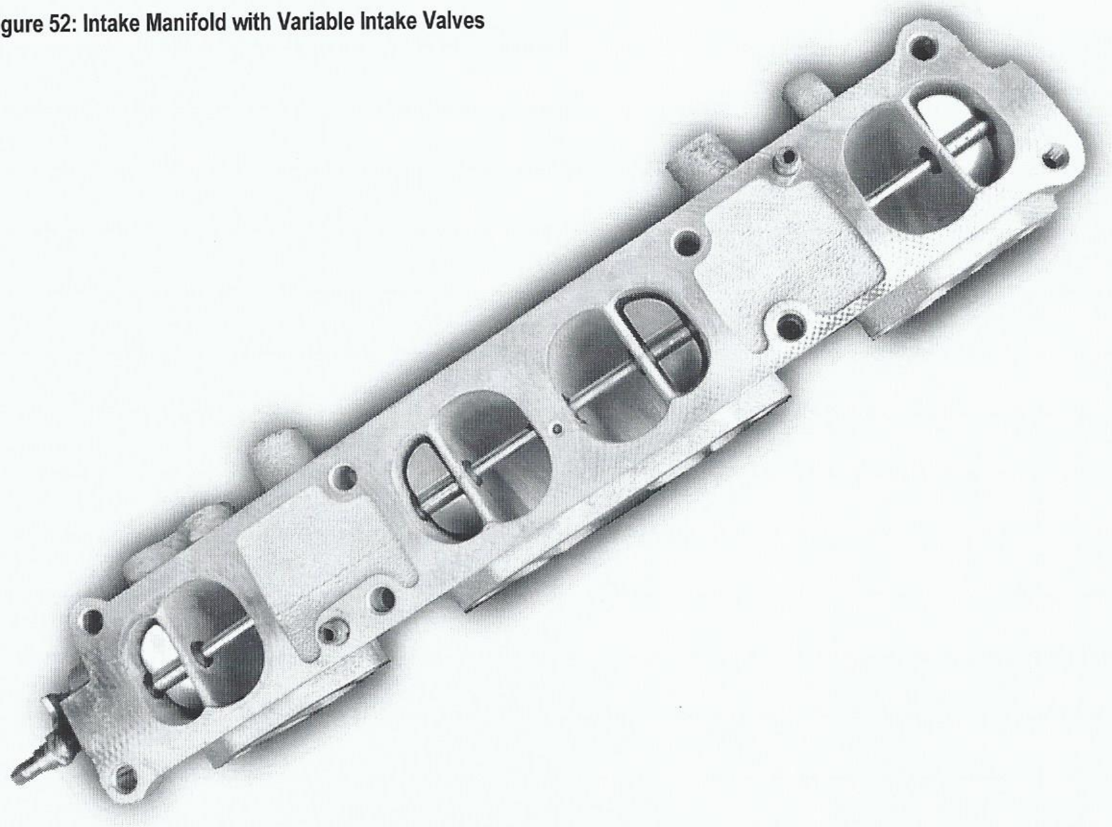
The Mazda 2.3L DISI engine incorporates a second Intake Air Temp Sensor into the MAP Sensor to compensate for temperature changes that occur after the air has passed through the Turbocharger and Intercooler.

The 3.0L (LF1 & LFW) VE SIDI utilises a MAP Sensor, however the 3.6L (LLT) does NOT.

INTAKE SYSTEM continued...

Variable Intake Manifold

Figure 52: Intake Manifold with Variable Intake Valves



Description

The Variable Intake Manifold allows the velocity of air entering the cylinder to be modified to suit engine speed and torque ranges.

During low to medium engine speed and torque ranges (such as cruising) the manifold valve will close off part of the Intake Manifold, increasing the velocity and flow path.

During high engine speed and torque ranges the manifold valve will open to reduce restriction.

The VE SIDI does NOT utilise a Variable Intake Manifold.

INTAKE SYSTEM continued...

Mazda 2.3L DISI Variable Intake Manifold

Description

The Variable Intake Manifold system employed on the Mazda 2.3L DISI is ECM controlled with a Vacuum Switch Valve and Vacuum Actuator. A Position Switch provides feedback.

Operation

The Variable Intake Manifold system is used only when the engine coolant temp is below 60°C and engine speed is below 3750 RPM. A key element in this system is that the Intake Manifold Valve closes off the air flow to one of the two Intake Valves in each cylinder as seen in *Figure 53*.

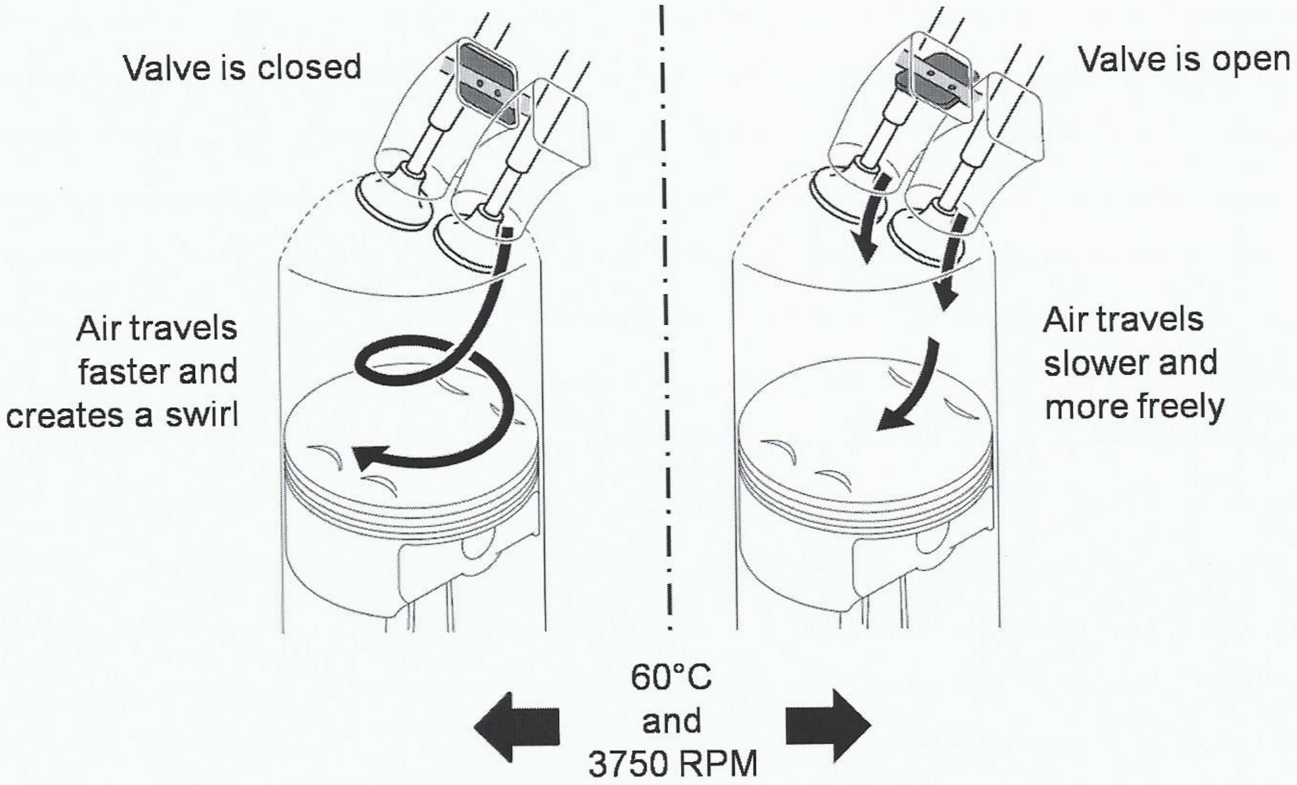

Valve is closed
Valve is open
Air travels faster and creates a swirl
Air travels slower and more freely
60°C and 3750 RPM

Figure 53: Mazda 2.3L DISI intake operation

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INTAKE SYSTEM continued...

VW 2.0L FSI Variable Intake Manifold

Description

The Variable Intake Manifold system employed on the VW 2.0L FSI is ECM controlled with an Electronic Motor and a Position Sensor provides feedback.

Operation

There are 2 main factors that dictate the closure of the Intake Manifold Valves:

1. Charge Mode – Homogeneous Lean (and Stratified if applicable)
2. Within the small pictured Torque/RPM window (see *Figure 54)*

Additional factors that activate the closure of the Intake Manifold Valves:

1. Start Up
2. Cold Idling
3. Overrun

A key element in this system is that the Intake Manifold Valve directs the air flow to one side of each of the eight Intake Valves as seen in *Figure 54*.

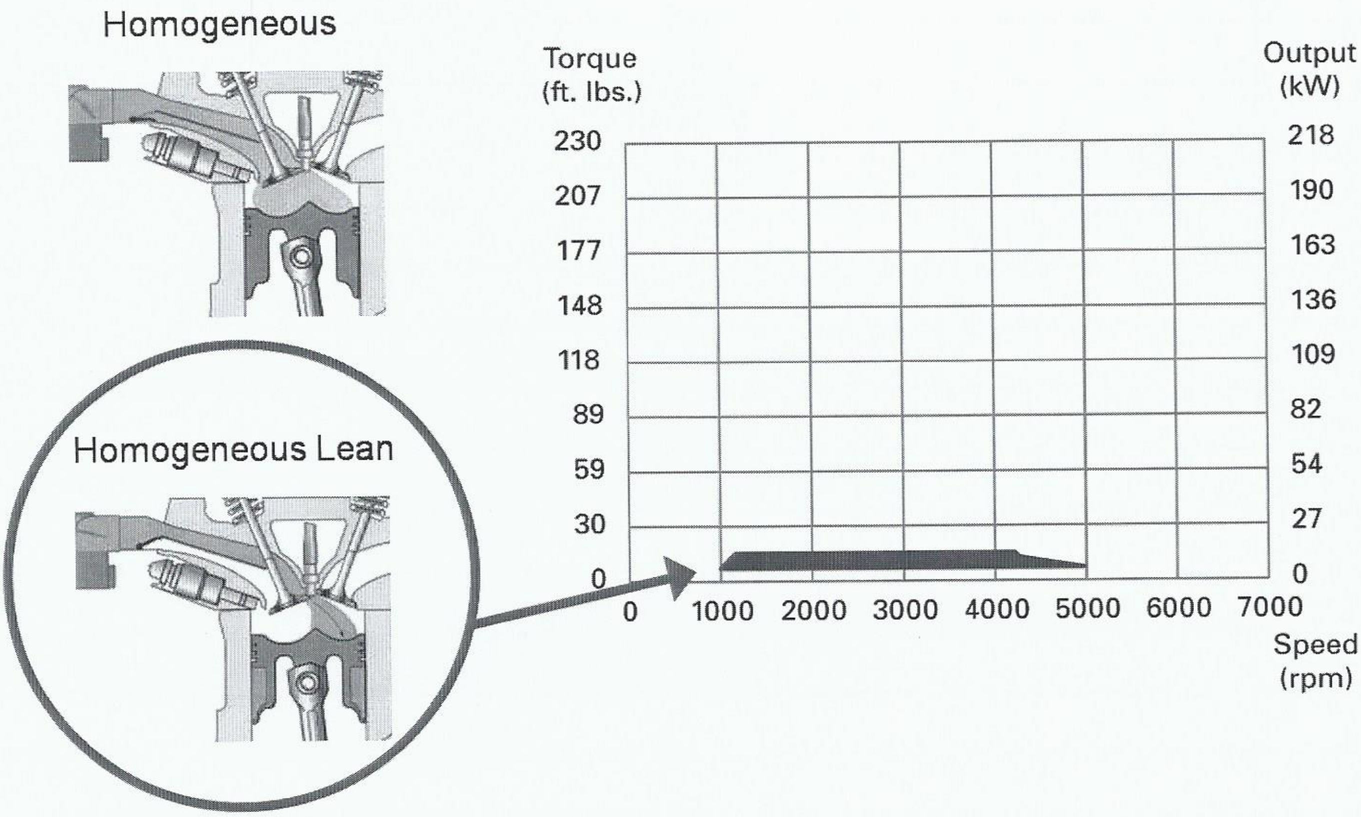

Homogeneous
Homogeneous Lean
Torque
(ft. lbs.)
230
207
177
148
118
89
59
30
0
Output
(kW)
218
190
163
136
109
82
54
27
0
0
1000
2000
3000
4000
5000
6000
7000
Speed
(rpm)

Figure 54: VW 2.0L FSI intake operation

INTAKE SYSTEM continued...

Brake Booster Vacuum Supply

With the operation of the Throttle Plate in DPI now having the ability to resemble that of a Common Rail Diesel (CRD) engine, an issue arises as to where a suitable source of vacuum can be attained to provide sufficient vacuum to the brake booster for reliable brake assistance.

There are 4 options in overcoming this issue:

1. Utilising a Vacuum Reservoir to store vacuum
2. ECM monitors the Vacuum Supply at the Brake Booster and will command the Throttle Plate to close if the vacuum level rises above the threshold.
3. Employing the use of a vacuum pump to supply vacuum when the supply from the engine is insufficient.
4. Use an Electronic/Hydraulic Brake Booster such as the Toyota UZJ200R Land Cruiser with DPI.

Applications

The VE SIDI utilises an electronically controlled vacuum pump to supply the Brake Booster when the supply from the engine is insufficient.

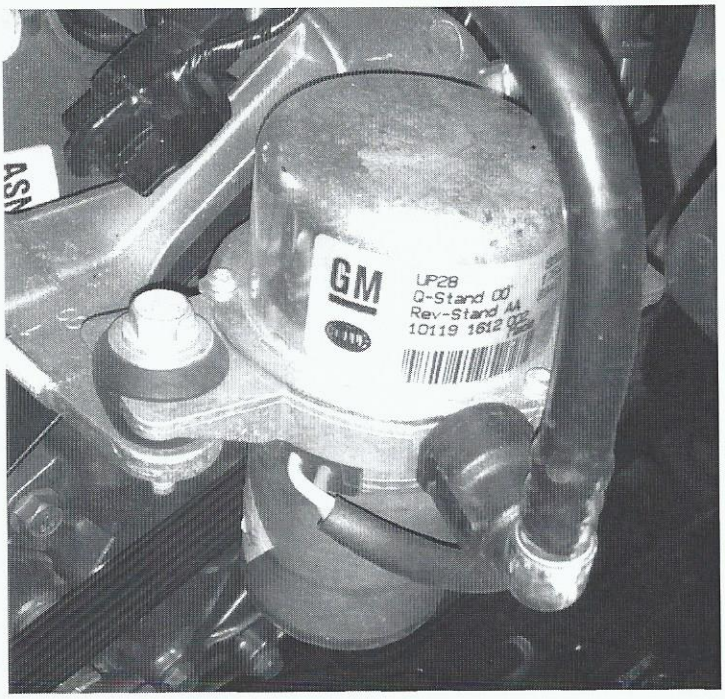
The System Incorporates:

- Brake Booster Pump Motor
- Brake Booster Pump Relay
- Brake Booster Vacuum Sensor
- Electronic Brake (ESP) Control Module

Brake Booster Pump Motor
The Brake Booster Pump Motor is located on the front of the right bank Cylinder Head.
The electric vacuum pump is controlled by the Electronic Brake (ESP) Control Module via the Brake Booster Pump Relay.

Brake Booster Vacuum Sensor
The Brake Booster Vacuum Sensor is located at the Check Valve on the Brake Booster.
The Electronic Brake (ESP) Control Module monitors this sensor and will command the Brake Booster Pump Motor ON if the vacuum supply from the engine is insufficient.

Figure 55: VE SIDI - Brake Booster Pump Motor



INTAKE SYSTEM continued...

Applications continued...

The VW 2.0L FSI has 1 of 2 different vacuum assistance systems depending on transmission fitment. Vehicles fitted with an Auto Trans utilise an electronically controlled vacuum pump, while Manual Trans vehicles use ECM control of the Throttle Plate to supply the Brake Booster when the supply from the engine is insufficient.

The System for Auto Trans Vehicles Incorporates:

- Brake System Vacuum Pump
- Brake Booster Vacuum Sensor
- ECM

The System for Manual Trans Vehicles Incorporates:

- Brake Booster Vacuum Sensor
- ECM
- Throttle Actuator Motor

Brake Booster Vacuum Pump

The Brake Booster Vacuum Pump is located on the front of the Auto Trans.
The electric vacuum pump is controlled by the Engine Control Module.

Brake Booster Vacuum Sensor

The Brake Booster Vacuum Sensor is located in a second the Check Valve style port on the opposite of the Brake Booster to the Check Valve.
The Engine Control Module monitors this sensor and will command the Brake Booster Pump Motor ON if the vacuum supply from the engine is insufficient.

Note: *Other VW FSI & TSI variations use a Vacuum Reservoir integrated into the Intake Manifold. These systems rely on ECM control of the Throttle Plate as backup.*

FLEXIBLE FUEL VEHICLES (FFV'S)

Overview

A Flexible Fuel Vehicle (also called flex-fuel vehicle or FFV) is a vehicle capable of running on any combination of undiluted petrol through to a blend of 15% petrol and 85% denatured Ethanol known as E85.

FFV's should not be confused with dual fuel vehicles which use two storage tanks, such as LPG and CNG powered vehicles. For a vehicle to be classified as an FFV it must store the various fuelling options in the one tank.

History

The first FFV was the 1908 Model T Ford which was capable of running on petrol or pure ethanol.

Applications

The Series II VE SIDI engines are both FFV's.
The engine has been upgraded with specially coated Valves & Seats.

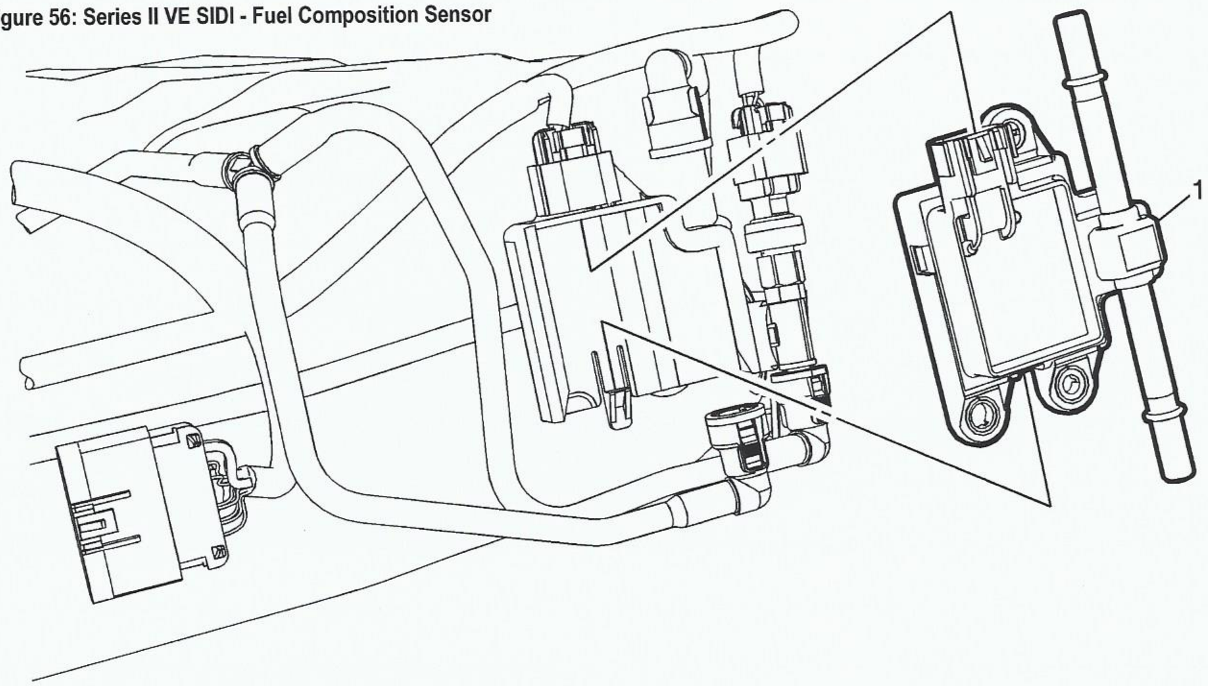
The system incorporates a Fuel Composition Sensor (also known as a Flex Fuel Sensor) located on the outside of the Fuel Tank. A sample of fuel is pumped by the Fuel Pump through the Fuel Composition Sensor which is spliced into the main fuel feed pipe.

Fuel Composition Sensor

The Fuel Composition Sensor incorporates a microprocessor and measures ethanol quantity and fuel temperature. It is also able to measure when the fuel is contaminated with water and will log a fault code (B2269).

The ECM receives a Pulse Width Modulated signal from the Fuel Composition Sensor and it will adjust the Fuel Injection and Ignition Timing to suit the ethanol grade.

Figure 56: Series II VE SIDI - Fuel Composition Sensor



Note: *The engine code for the 3.0L engine changed from LF1 to LFW when it became an FFV.*

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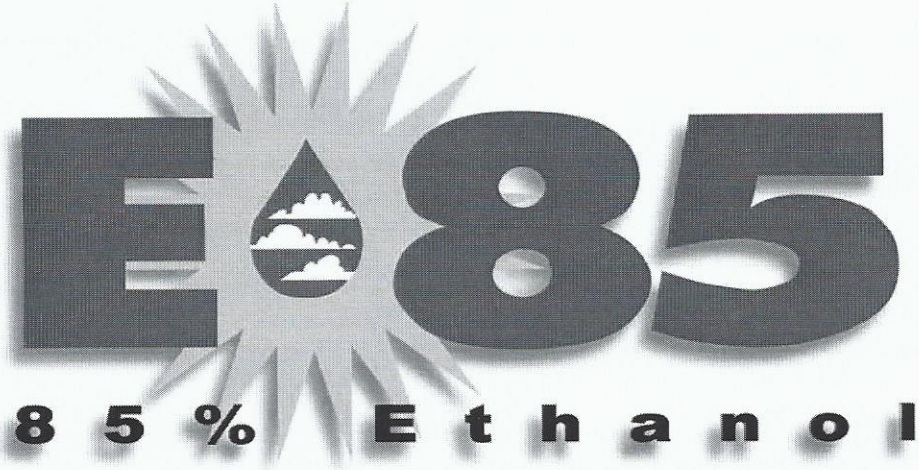
BIO-FUEL (E85)



Bio-Fuel as it is marketed or E85 is a blend of 15% petrol and 85% denatured ethanol although in colder climate areas it may be adjusted back to 30% petrol and 70% denatured ethanol.
Denatured means that the ethanol has been altered to make it inconsumable, this is done under government regulation. Ethanol is denatured by blending the 100% ethanol with approximately 4.5% petrol.
Affectively this means that if measured E85 only contains approximately 81% Ethanol.

Ethanol is alcohol (a colourless liquid) generally manufactured by the fermentation of sugars and carbohydrate polymers from grains or sugars. Ethanol for use in automotive fuel comes mostly from wheat, sugar is the next most popular source.

E85 only contains approximately 70% of the energy found in 91 RON unleaded petrol (ULP). What this means for Flexible Fuel Vehicles is that their fuel mileage and performance are severely compromised while running on E85 as compared to ULP. Adjustments in engine control help to compensate for these losses but they are still significant.

This is not to say that E85 is completely inefficient. Vehicles designed to run ONLY on E85 are claiming to achieve better fuel economy (L/100km) than many ULP vehicles.

A study by the US Dept. Of Energy found that nearly all exhaust emissions were reduced except for three. One of which, Acetaldehyde saw increases of nearly 1,800%.

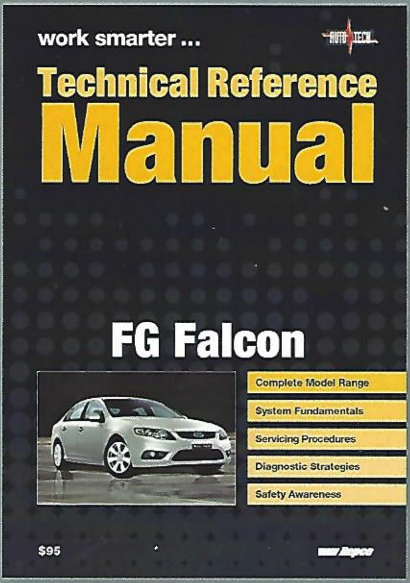
Note: *As of the 1st of July 2011 all ULP sold in NSW will contain up to 10% Ethanol. For people running old vehicles that are not E10 compatible they are now required to run on Premium Unleaded (PULP)*

Note: *You can measure the approximate Ethanol content of any fuel with this simple test.*

1. *Place 90ml of ULP in a bottle (preferably with 1ml graduations)*
2. *Add 10 ml of water and tighten the lid*
3. *Shake strongly for 15 seconds*
4. *Remove the lid and release any pressure*
5. *Refit the lid and Shake strongly for a further 15 seconds*
6. *Place the bottle on a level surface and leave standing for 5 minutes*
7. *Measure the amount of water in the bottom. Because ethanol is absorbed by water this process has drawn most of the ethanol out of the Fuel and into the water. Any amount of water above the original 10ml in the bottom of the bottle indicates the ethanol content (i.e. 20ml = E10).*

Warning: Ethanol blended fuels should not be used in marine or aircraft applications.

Technical Training Manuals available: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Technical Reference

Manual

FG Falcon

- Complete Model Range
- System Fundamentals
- Servicing Procedures
- Diagnostic Strategies
- Safety Awareness

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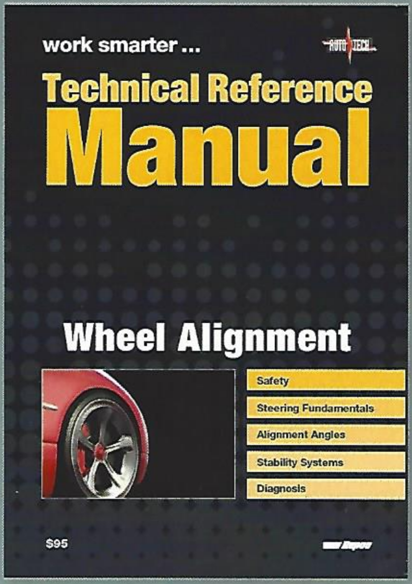
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Wheel Alignment

- Safety
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- Stability Systems
- Diagnosis

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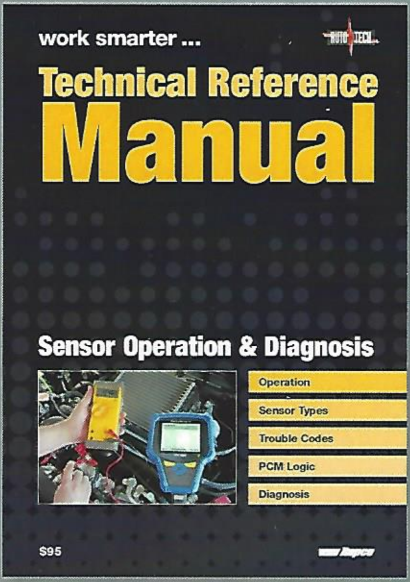
Wheel Alignment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Technical Reference

Manual

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- Sensor Types
- Trouble Codes
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- Diagnosis

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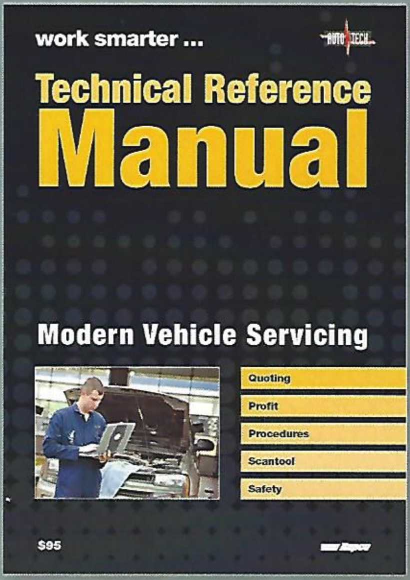
Sensor Operation
& Diagnosis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